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EFFECT OF LABORATORY AMBIENT CONDITIONS ON EXHAUST EMISSIONS

Scott Research Laboratories, Incorporated
San Bernardino, California

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NAPCA Project Number CPA 22-69-156

Prepared for

NATIONAL AIR POLLUTION CONTROL ADMINISTRATION
DEPARTMENT OF HEALTH, EDUCATION AND WELFARE

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Prepared for

National Air Pollution Control Administration
Consumer Protection and Environmental Health Service
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Department of Health, Education and Welfare
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SUMMARY

This report presents the results of a test program to evaluate the effect of ambient temperature and humidity conditions on exhaust emission levels.

Concentration measurements of unburned hydrocarbons, carbon monoxide, carbon dioxide, and nitrogen oxide, as well as mass measurements of unburned hydrocarbons, carbon monoxide, and oxides of nitrogen were made at 20 different combinations of ambient temperature and humidity conditions. Five American-made vehicles and three foreign vehicles were evaluated at each of the 20 different test conditions. The test conditions were selected to represent the range of temperature and humidity values encountered at most exhaust emission testing facilities in the continental United States.

Linear and general quadratic regression equations were developed from the test data to determine if suitable correction factors could be formulated for the purpose of correcting measured exhaust emission data to standard temperature and humidity values. The results indicate that nitric oxide or oxides of nitrogen values can be corrected for the effects of temperature and humidity with a high degree of confidence. The effects of temperature and humidity on the carbon monoxide emissions can be predicted with only a moderate degree of confidence. Hydrocarbon emissions cannot be successfully correlated with the effects of temperature and humidity.

1. INTRODUCTION

Generally speaking, most exhaust emission testing has been and is now being performed in laboratories where ambient air quality is not controlled. It has been observed that ambient air temperature and humidity do affect vehicle exhaust emission test results, most noticeably in the measuring of oxides of nitrogen.

Scott Research Laboratories, Inc., has recently completed a study of the effect of laboratory ambient conditions on exhaust emissions. Testing was conducted on five typical American-made automobiles and three foreign-made vehicles. Control of ambient air conditions was accomplished at Scott Research Laboratories' all-weather chassis dynamometer room located in San Bernardino, California. This facility is equipped for controlling air temperature over the range 0-150°F and controlling humidity level from ambient to virtually 100%.

2. PROGRAM DESCRIPTION

2.1 GENERAL APPROACH

The proposed test program was designed to determine the effects of ambient temperature and humidity on exhaust emissions. The program was carefully designed to yield data amenable to analysis by statistical and computer techniques so that maximum information on the effects under study could be developed.

A survey of the temperature-humidity data for 9 major United States cities and a review of the average relative humidity profiles for the United States for a 39-year period were carried out in order to establish realistic test conditions. The test vehicles were acquired after first screening them for suitability. The vehicles selected were tuned to manufacturer's specifications.

The basic program consisted of running 20 different temperature and humidity combinations in duplicate on each vehicle. Variability was reduced by random selection of test conditions. The exhaust emissions were measured according to the Federal procedure with the addition of oxides of nitrogen measurements and simultaneous mass emission measurements.

Multiple linear regressions were run on the data for each vehicle, and for a combination of the five American-made vehicles. Nonlinear (general quadratic) regression equations were also developed and analyzed to determine if the general quadratic surface gave a better fit than the regression plane.

2.2 TEST CONDITIONS - GENERAL

Twenty different combinations of temperature and humidity were established in the Scott All-weather room to measure their effects on various exhaust emission levels. The twenty test conditions are presented in Table 2.1. The randomly selected schedule for conducting these tests is shown in Tables 2.2 and 2.3. Table 2.2 presents the schedule for the initial round of testing (Phase I) and Table 2.3 details the pattern used for the duplication round (Phase II).

2.2.1 Test Facilities

The test facility for conducting this study enabled Scott Research effectively to control the temperature throughout the required range (59°F to 95°F). Humidity control was exercised throughout the range from ambient conditions to the maximum required value of 180 grains of water per pound of dry air. On some occasions it was not possible to test at low humidity conditions because of higher ambient humidity levels. For these occurrences, deviations from the test schedule were necessarily invoked to enable completion of the program within the required time. As soon as ambient humidity dropped to acceptable levels, testing was continued per the original test format.

The original test schedule of randomly selected conditions was thus observed wherever possible by the test operator. For ease of monitoring, the various temperature and humidity combinations were obtained based on dry bulb and wet bulb thermometer readings. Dry bulb readings (indicative of the desired test temperature) were controlled to ± 3°F. Water vapor levels were adjusted until wet bulb readings (indicative of humidity level) read within ± 0.5°F of the required value at the nominal test temperature.

Table 2.1

Temperature and Humidity Study
Test Conditions

Station	Temp. °F	Moisture gr./lb.	Relative Humidity, %
1	59	20	28
2	59	40	54
3	59	60	80
4	71	20	18
5	71	40	35
6	71	60	53
7	71	80	70
8	83	20	12
9	83	40	24
10	83	60	35
11	83	80	47
12	83	100	59
13	83	120	70
14	83	140	82
15	95	40	17
16	95	60	25
17	95	80	33
18	95	100	40
19	95	140	56
20	95	180	72

Table 2.2

Random Selection of Test Conditions*

Test No.	Car 1	Car 2	Car 3	Car 4	Car 5	Car 6	Car 7	Car 8
1	6	6	6	6	6	6	6	6
2	5	5	5	5	5	5	5	5
3	10	10	10	10	10	10	10	10
4	4	4	4	4	4	4	4	4
5	19	19	19	19	19	19	19	19
6	11	11	11	11	11	11	11	11
7	3	3	3	3	3	3	3	3
8	8	8	8	8	8	8	8	8
9	13	13	13	13	13	13	13	13
10	17	17	17	17	17	17	17	17
11	9	9	9	9	9	9	9	9
12	16	16	16	16	16	16	16	16
13	2	2	2	2	2	2	2	2
14	7	7	7	7	7	7	7	7
15	20	20	20	20	20	20	20	20
16	12	12	12	12	12	12	12	12
17	18	18	18	18	18	18	18	18
18	15	15	15	15	15	15	15	15
19	14	14	14	14	14	14	14	14
20	1	1	1	1	1	1	1	1

* Taken from "Statistical Techniques for Collaborative Tests," by W. J. Youden.

Table 2.3

Random Selection of Test Operations*

Test No.	Car 1	Car 2	Car 3	Car 4	Car 5	Car 6	Car 7	Car 8
21	5	5	5	5	5	5	5	5
22	14	14	14	14	14	14	14	14
23	17	17	17	17	17	17	17	17
24	12	12	12	12	12	12	12	12
25	2	2	2	2	2	2	2	2
26	10	10	10	10	10	10	10	10
27	13	13	13	13	13	13	13	13
28	8	8	8	8	8	8	8	8
29	7	7	7	7	7	7	7	7
30	15	15	15	15	15	15	15	15
31	11	11	11	11	11	11	11	11
32	18	18	18	18	18	18	18	18
33	16	16	16	16	16	16	16	16
34	3	3	3	3	3	3	3	3
35	9	9	9	9	9	9	9	9
36	4	4	4	4	4	4	4	4
37	6	6	6	6	6	6	6	6
38	1	1	1	1	1	1	1	1
39	20	20	20	20	20	20	20	20
40	19	19	19	19	19	19	19	19

* Taken from "Statistical Techniques for Collaborative Tests," by W. J. Youden.

2.2.2 Test Scheduling

Because of delays in the start-up of actual testing, it was necessary to complete a greater number of tests per day than was originally scheduled. Testing was therefore conducted during two work shifts per day. Additionally, it was judged safe to apply external heat to the engines when the difference between the ambient temperature of the garage used to soak the vehicles and a desired test temperature exceeded 20°F. Various precautions were taken to insure that the test vehicle was stabilized at the test temperature, as indicated by engine water jacket and oil sump thermocouples, before conducting a specific test. The All-Weather Room air blower was operated to force air (at test temperature) toward the vehicle's engine compartment at 20 mph. Also, heat lamps were directed at the engine block and oil pan from a minimum distance of two feet. Carburetors and choke mechanisms were shielded from the heat sources to prevent localized overheating. When a vehicle reached a desired test temperature, the heat lamps were de-energized and the engine was checked for temperature stablization.

The addition of heat to achieve stabilization at test temperature was required primarily just at the maximum temperature condition of 95°F. However, engine heating was used to obtain stabilization at 83°F on rare occasions.

On a few occasions the vehicle's engines were at a slightly higher temperature than desired. Cool air was directed toward the engine compartment until the desired temperature stabilization was achieved.

Thermocouples were located in the cylinder head water passages of all vehicles (except Porsche). An oil dipstick with a thermocouple affixed to it was fabricated to fit all test vehicles. Stabilization of temperature at both sensors was prerequisite to commencement of exhaust tests.

2.3 TEST VEHICLES

2.3.1 Test Vehicles - General Description

The eight test vehicles were selected to represent the range of carburetion systems and engine designs most often found in the United States automobile population. All five of the American made vehicles had popular size V-8 engines with conventional 2-barrel downdraft carburetors. One foreign vehicle was equipped with a variable-orifice air-valve carburetion system on a water-cooled inline 4-cylinder engine (Volvo); another was equipped with a fuel injection system on a water-cooled inline 4-cylinder engine (Alfa-Romeo); and the third foreign car was equipped with a complex downdraft carburetion system on an air-cooled horizontally opposed 6-cylinder engine (Porsche). All vehicles were 1969 models with approximately 12,000 miles at the start of testing. None of the vehicles was equipped with an exhaust manifold reactor or air injection equipment.

Table 2.4 presents the itemized descriptions of the test vehicles.

2.3.2 Test Vehicle - Tuneup and Screening

All vehicles were tuned to manufacturer's specifications as indicated by the vehicle inspection example sheet shown in Figure 2.1.

Table 2.4 Description of Test Vehicles

Vehicle No.	1	2	3	4	5	6	7	8
Make	Chev.	Chev.	Ford	Ford	Plym.	Volvo	Alfa	Porsche
Year	1969	1969	1969	1969	1969	1969	1969	1969
Mileage @ Start unladen weight	3,855	3,855	4,004	4,004	3,805	2,619	2,138	2,250
Engine Type	V-8	V-8	V-8	V-8	V-8	I-4	I-4	Opp-6
Engine CID	327	327	390	390	318	121	108	121
Cooling System	Water	Water	Water	Water	Water	Water	Water	Air
No. of Carb.	1	1	1	1	1	2	-	2
No. of bbls/carb.	2 bbl	2 bbl	2 bbl	2 bbl	2 bbl	1 bbl	Fuel Inj.	3 bbl
Manuf. of Carb.	Carter	Carter	Autolite	Autolite	Carter	Stromberg	-	Weber
Air Conditioner	Yes-off	Yes-off	Yes-off	Yes-off	Yes-off	Yes-off	No	No
Spark Advance	2^{o} BTC	2^{o} BTC	6^{o} BTC	6^{o} BTC	TDC	10^{o} TDC	2^{o} BTC	TDC
Idle RPM	600 D	600 D	550 D	550 D	650 N	700 D	950 N	900 N
Transmission	2-sp. Auto	2-sp. Auto	3-sp. Auto	3-sp. Auto	3-sp. Auto	3-sp. Auto	5-sp. Man.	4-sp. Man.
Dyno Load								
Dyno Inertia	4,000	4,000	4,000	4,000	4,000	3,000	3,000	3,000

A = Adjust
R = Replace

Figure 2.1

Pre Emission Test Tuneup
Summary on Vehicle
Project #2846

Car #_____ Odo_____, miles Car Make_____

Engine CID_____ Total Diagnosis Time_____hrs. Total Tuneup Time_____hrs.

IGNITION SYSTEM	DIAGNOSIS	Checked by
Firing Line		
o Required Voltage, kv		
o Coil Available Voltage, kv		
Spark Line		
Coil Oscillations		
Cond. Oscillations		
Points Opening		
Points Closing		
Dynamic Compression (speed change %)	1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____	

IGNITION SYSTEM ADJUSTMENTS	As Rec'd	Spec.	Adj (A) or Replace (R)	
Spark Plug Gap, inches				
Ignition Point Dwell, distr. degrees				
Ignition Timing, crankshaft degrees				
Total Advance, crankshaft degrees				
Mechanical Advance, crankshaft degrees				
Vacuum Advance, crankshaft degrees				

SRD-154a

Figure 2.1 (cont'd)

Pre Emission Test Tuneup
Summary on Vehicle
Project #2846
(cont.)

CARBURETOR ADJUSTMENTS	As Rec'd.	Spec.	Adj (A) or Replace(R)	Checked By
Idle RPM, Drive/Vacuum, in. Hg				
Idle RPM, Neutral/Vacuum, in. Hg				
Idle RPM (throttle positioner off)				
Idle CO, %/AF Ratio				
Exhaust CO @ 2500 RPM, Neutral				

AIR CLEANER

Element Condition, AC Tester				
Thermostatic Intake Opening Temp, ^{o}F				

EXHAUST CONTROL VALVE	Frozen Closed	Frozen Open	Free	
Heat Riser Valve Operation				

Upon completion of the mechanical tune-up, each vehicle was given a Federal Hot Start exhaust emission test to ensure that none of the vehicles were excessively high emitters. The results of these screening tests are presented in Table 2.5.

As indicated by these results, the five American-made vehicles were generally acceptable based on the screening test results. The Volvo exhibited high CO values during the first test. Subsequently, the carburetors were adjusted for a leaner idle CO value. This change, however, had little effect on the weighted CO results. No further attempts were made to reduce the weighted CO value as the retested weighted HC value was satisfactory. Initially, this test vehicle was prepared by a factory representative.

The Alfa test vehicle was also prepared by factory service representatives prior to screening. Exhaust emission results were not favorable, and unfortunately, additional efforts to improve the situation (by the factory mechanic) were not successful. It should be noted that a factory engineering change issued approximately January 1, 1970, was incorporated into this vehicle for the second round of testing. The results of the change (injection pump timing and initial spark advance) greatly improved the HC emission levels. It was not deemed feasible to try and locate a substitute test vehicle.

The Porsche test vehicle exhibited reasonable CO values (just slightly over 1.5%) during the screening test; however, unburned HC values were higher than desired. All elementary tune-up specifications were found to be within limits. Further efforts to reduce the HC levels were not

Table 2.5

Vehicle Screening Test Results

Vehicle Number	Year & Make	Engine CID	Date Tested	Hot Test Emission Results HC, ppm	CO, %	Remarks
1	'69 Chevrolet	327	9-11-69	263	0.75	
2	'69 Chevrolet	327	10-23-69	365	0.89	
3	'69 Ford	390	9-10-69	157	0.72	
4	'69 Ford	390	9-10-69	163	0.88	
5	'69 Plymouth	318	9-9-69	226	0.84	
6	'69 Volvo	121	9-25-69	237	2.70	
6A	'69 Volvo	121	10-6-69	170	2.73*	* Carburetor idle adjustment (leaner) did not improve weighted CO.
7	'69 Alfa	108	9-23-69	542**	3.23**	** Not feasible to locate replacement vehicle.
8	'69 Porsche	121	9-17-69	593**	1.63	** Not feasible to locate replacement vehicle.

NOTE: Alfa test vehicle was retuned (by factory representatives) after first round of testing; resultant HC values were much lower during duplicate round of testing.

sufficient to achieve Federal specification emission levels on this particular vehicle. Since it was not feasible to obtain a similar replacement test vehicle, it was decided to use the original vehicle for further testing.

2.4 TEST PROCEDURES

2.4.1 Federal Cold Start Emission Tests

The test program was designed to conduct a total of 320 Federal cold start exhaust emission tests. The Federal Register of June 4, 1968, was referred to for all applicable control items. Emissions measured were unburned hydrocarbons, carbon monoxide, and carbon dioxide, all by non-dispersive infrared analyzers. Simultaneously, nitric oxide was measured by NDIR.

2.4.2 Proposed Mass Emission Tests

Concurrently with the aforementioned emission determinations, a mass emission observation was made during each test. Diluted exhaust gas was sampled, collected in a Mylar bag, and analyzed to determine mass emission levels of total unburned hydrocarbons (by the Flame Ionization Detection method), carbon monoxide, nitric oxide (NO), and nitrogen dioxide (NO_2). Analyses of the room background air quality were performed in a similar manner for the purpose of obtaining net mass emission values for each test. The techniques used in this regard were generally in accordance with the proposed specifications for "... Exhaust Emissions, Fuel Evaporative Emissions, and Smoke Emissions Applicable to 1972 and Later Vehicles."

Other supplementary data recorded were barometric pressure, vehicle odometer readings, date, time, and dynamometer loading.

2.4.3 Test Fuel

Fuel used for this program was Indolene 30 per the current Federal Register. Each vehicle's fuel tank was initially drained and the test fuel was added. Therefore, all tests were conducted using the appropriate test fuel from the vehicle's tank rather than an external supply.

2.4.4 Test Preparations

Each vehicle was allowed to soak in the soaking garage for a minimum of 12 hours prior to cold start testing. When ready for evaluation, the vehicle was pushed into position and secured for dynamometer operation. The vehicle's temperature characteristics were ascertained to determine the necessity of external heating or cooling to bring it to test conditions. While the vehicle was stabilizing, instrumentation was prepared and given an initial calibration using the applicable span gases for determining concentration emissions. Additionally, a similar calibration of instruments was performed following each test. Calibration of the instrument train using the full range of calibration gases was effected whenever a new (replacement) calibrating gas was installed, following any instrument disassembly, and at various other intervals throughout the test program.

2.4.5 Test Procedures

To obtain exhaust emission data in accordance with the foregoing procedures, the following test pattern was followed:

a) Vehicle was prepared for conducting a Federal cold start test in accordance with the June 4, 1968, Federal Register, and the temperature/humidity requirements of the subject contract.

b) Calibration of instruments necessary for the evaluation of exhaust emissions (concentration basis) was performed.

c) A Federal cold start test was conducted, using a 40-second idle mode for the first cycle.

NOTE: By agreement with the contracting office, the 40-second idle mode was used instead of a 20-second idle mode as suggested in the proposed 1972 Mass Exhaust Emission procedure. In effect, this requirement makes the Federal cold start results valid but slightly biases the mass emission results which supposedly reflect a 20-second idle mode for the first cycle.

d) Concentration exhaust emission measurements were recorded for test cycles 1-4 (warm-up cycles) and cycles 6 & 7 (hot cycles).

e) The vehicle continued operation for nine (9) complete cycles. Mass exhaust emission samples were collected from "key on" to 5 seconds after the completion of the 9th cycle. Concurrently, a bag sample of background room air was collected over the same time interval.

f) Instrumentation necessary for analysis of the mass emission bag samples was calibrated.

g) The diluted mass exhaust emission samples were analyzed.

h) All equipment was prepared for the next test vehicle.

2.4.6 Vehicle Mechanical Inspection

The test vehicles were checked for mechanical malfunction and general tune-up condition whenever test results indicated the need. All vehicles were given a complete reinspection following the completion of the first round of testing.

The exception to the above procedure was the Number 8 test vehicle (Porsche). This car exhibited a degradation of exhaust emission levels as the first round of testing progressed. Approximately half way through the first round of testing, the vehicle was inspected at Scott Research facilities for all aspects of tune-up performance except the carburetion system. The applicable tune-up factors were found to be satisfactory. Consequently, the carburetion system was considered suspect, especially since the vehicle's CO characteristics were particularly abnormal. Southern California technical representatives for the Porsche Company directed us to the nearest Porsche service agency. The vehicle was taken to an authorized Porsche dealer where the service manager indicated that the vehicle was operating too lean, according to their chassis dynamometer tests. Subsequently, the vehicle's carburetion system was adjusted by the dealer's service department to a supposedly acceptable performance level. Upon return of the vehicle to Scott Research facilities, it was found that the Porsche's carburetion system was obviously enrichened. The net effect was higher weighted CO values; however, unburned hydrocarbon values were approximately 30% less (640 ppm HC versus 900 ppm HC). In this new "state-of-tune" the test vehicle showed signs of plug fouling unless periodically driven at high speed.

Seven-mode cycle testing proved to be an unreasonable operating pattern for this test vehicle. Fifteen-mph cruise modes had to be driven in low gear to prevent engine stumbling.

Necessary corrections to all test vehicles were made to bring each car back to its initially-prepared condition (except Porsche). Also, the Alfa test vehicle was tuned to reflect the recommendations of the factory engineering change as discussed in Section 2.3.2.

The results of the mid-program inspection are shown in Table 2.6.

2.4.7 Test Procedures (For Duplicate Round of Testing)

The vehicles were tested during the second phase in an identical manner to first-phase testing. The pattern of testing followed is shown in Section 2.4.5. Phase II testing was generally trouble-free except for sporadic indications of spark plug fouling with the Porsche. After about every other test, this car was driven at high speeds in an attempt to stabilize the vehicle for further testing.

2.5 TEST APPARATUS

The test apparatus used was generally compliant with all aspects of the requirements of the contract. A schematic of the entire system is presented in Figure 2.2.

2.5.1 Exhaust Gas Analysis System (For Determining Weighted Emissions)

The "basic" exhaust gas analysis system is nearly identical to the schematic presented in the Federal Register, June 4, 1968. Slight alterations were required to integrate this system with the other associated gas analysis systems. The necessary alterations did not functionally affect the performance of the basic system except for a slight increase in "lag" time attributable to the lengthy sample line.

The system was capable of determining ppm unburned HC (both high HC levels and low HC levels), percent carbon monoxide, and percent carbon dioxide, all by the nondispersive infrared technique.

Table 2.6

Mid-Test Vehicle Inspection

Vehicle No.	Vehicle Make	Engine CID	Tune-up Items Out of Specification	Corrective Action
1.	Chev.	327	1. Vacuum advance = 20° 2. Initial timing = 3°BTC 3. Ignition dwell = 33°	1. Replaced vacuum advance unit; advance = 16° 2. Reset to 2°BTC 3. Reset to 28°-32°
2.	Chev.	327	1. Vacuum advance = 21° 2. Ignition timing = 4°BTC 3. Ignition dwell = 33° 4. Choke action erratic	1. Replaced unit; adv. = 16° 2. Reset to 2°BTC 3. Reset to 28°-32° 4. Cleaned
3.	Ford	390	None	None
4.	Ford	390	1. Initial timing = 5°BTC	1. Reset to 6°BTC
5.	Plym.	318	1. Cracked hose on choke pull-down mechanism	1. Replaced
6.	Volvo	121	1. Ignition dwell = 56° 2. Initial timing = 8°BTC	1. Reset to 59°-65° 2. Reset to 10°BTC
7.	Alfa	108	1. Injection pump timing not to specification	1. Injection pump timing reset to new factory prescribed setting
8.	Porsche	121	1. Vehicle performance indicated need for carburetion work	1. Complete tune-up performed by authorized Porsche dealer

Notes: In addition to above adjustments, all spark plugs were regapped to normal settings.

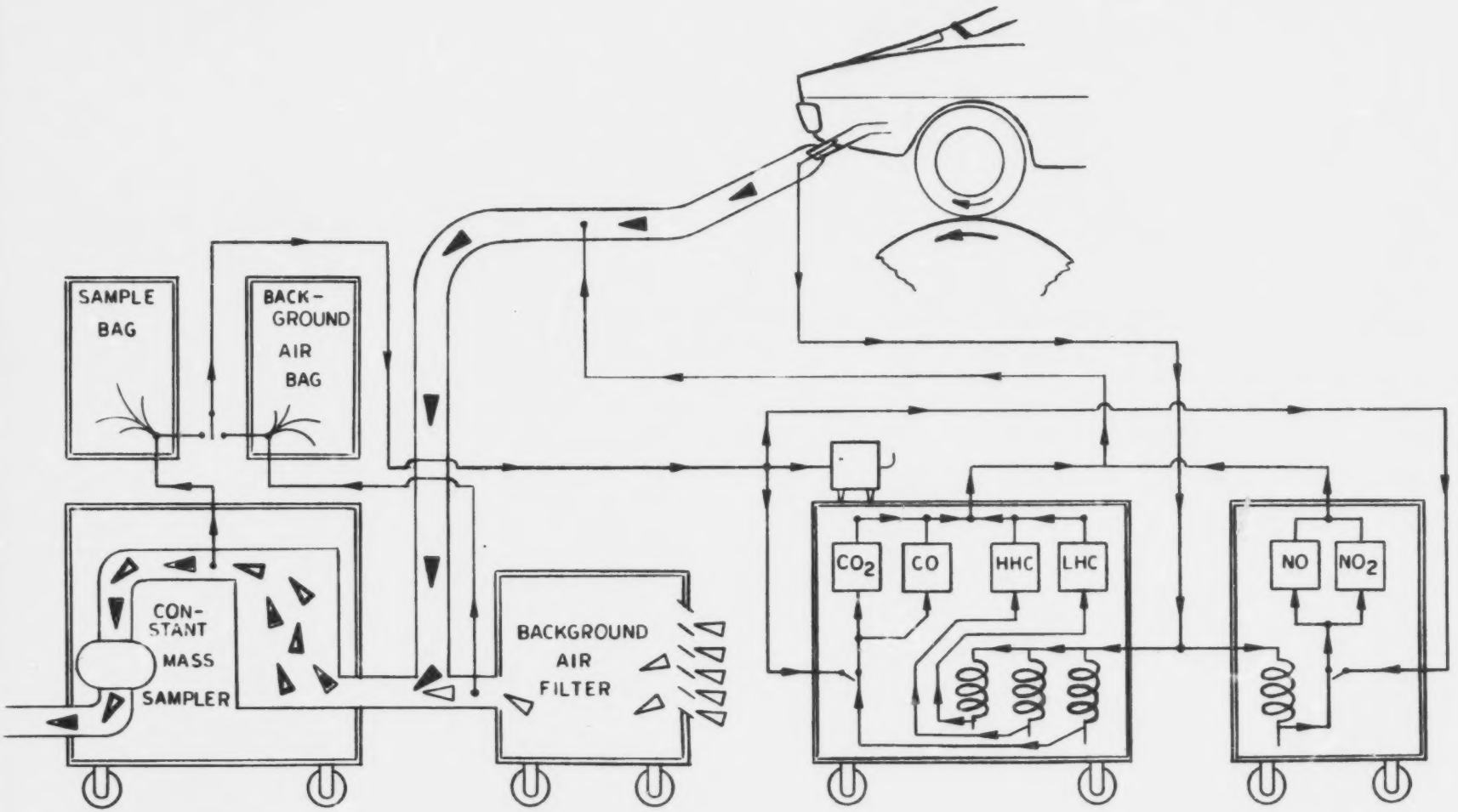

Figure 2.2
Exhaust Gas Analysis System

2.5.2 Oxides of Nitrogen Analysis System

The subject analysis system was designed to operate in parallel with the "basic" system, as well as being capable of diluted exhaust analysis (for mass emission determination). Nitric oxide (NO) was monitored during the Numbers 1-4 warm-up cycles and during the Number 6 & 7 hot cycles. For analysis of the mass exhaust emission sample, measurements of ppm nitric oxide (NO) and nitrogen dioxide (NO_2) were obtained.

The NO analyzer was a nondispersive infrared instrument. The instrument had dual-range capabilities for both raw and diluted exhaust analysis. The NO_2 analyzer was a nondispersive ultraviolet instrument.

2.5.3 Mass Exhaust Emission Analysis System

The system used for collecting and analyzing vehicle mass exhaust emission components was integrated with the other systems. Care was taken to ensure that all exhaust gas passing through the "basic" system was returned to the inlet side of the mass emission collection system during the cycle testing. Emissions measured were; ppm unburned HC (by the Flame Ionization Detection method), low level carbon monoxide (percent CO by NDIR), low level nitric oxide (ppm NO by NDIR), and nitrogen dioxide (ppm NO_2 by the nondispersive ultraviolet technique).

All instruments in the analysis train had accompanying refrigerated water baths on the inlet side of their detector circuits (except the FID). The FID instrument had a glass wool water vapor separator on the sample inlet line.

3. TEST RESULTS

The test data were reduced in accordance with standard procedures to yield weighted emission volume concentrations of unburned hydrocarbons (ppm), carbon monoxide (%), and nitric oxide (ppm). Additionally, diluted bag samples were measured for the purpose of calculating the net mass exhaust emissions of unburned hydrocarbons, carbon monoxide, and oxides of nitrogen--all in grams per mile. The method used to calculate the mass emissions is shown in Appendix A.

The corrected test data are given in Tables B-1 through B-16 of Appendix B.

3.1 DATA ANALYSIS

The individual exhaust emission values shown in Appendix B were processed by computer to generate and analyze regression equations to determine which may be used reliably to correct exhaust emission values for the effects of temperature and humidity. Both linear and quadratic step-wise regression analyses were performed to generate the best possible fits to the data to determine the effect of the two variables on the exhaust emission measurement.

3.1.1 Linear Regression Analyses

The exhaust emission values for each test (both concentration and mass emissions) were keypunched for computer processing. Data were processed using standard step-wise regression programs to generate linear correction equations for each vehicle and each particular exhaust emission. Equations generated for the individual vehicles were of the general form:

$$E = \bar{E} + a_1 \Delta T + a_2 \Delta H$$

where;

E = Estimated emission value corrected to the mean temperature and humidity condition observed during the test program.

$\bar{E}$ = Mean emission level observed for a vehicle throughout the range of temperature and humidities tested.

a_1 = Regression coefficient for the effect of temperature.

$\Delta T = T - \bar{T}$; i.e., the test temperature minus the mean temperature (mean temperature equals 80.6°F for all vehicles where the complete range of temperatures was tested).

a_2 = Regression coefficient for the effect of humidity.

$\Delta H = H - \bar{H}$; i.e., the test humidity minus the mean humidity (mean humidity equals 74 grains per pound for all vehicles where the complete range of humidities were tested).

The results of the linear step-wise regression analysis are shown in Appendix C, Tables C-1 through C-6. In each case the regression equation indicates the more significant of ΔT and ΔH by the sequence in which they appear. Thus, if ΔH appears before ΔT, it indicates that the simple correlation of the emission with humidity is greater than that with temperature.

It should be noted that these linear equations are easily reformulated to represent deviations from standard temperature and humidity values, T_s and H_s, with the following linear transformations:

$$\Delta T = T - T_s$$
$$= (T - \bar{T}) + (\bar{T} - T_s)$$

$$\Delta H = H - H_s$$
$$= (H - \bar{H}) + (\bar{H} - H_s)$$

Noting that $\bar{T} - T_s$ and $\bar{H} - H_s$ are constants, and known when T_s, H_s are specified, the conversion is:

$$E = \bar{E} + a_1 (T - \bar{T}) + a_2 (H - \bar{H})$$

$$= [\bar{E} + a_1 (\bar{T} - T_s) + a_2 (\bar{H} - H_s)] + a_1 (T - T_s) + a_2 (H - H_s).$$

The net effect, then, is simply the replacement of the original constant term, $\bar{E}$, by another constant term. The values of the regression coefficients remain the same, of course.

3.1.2 Quadratic Regression Analyses

A quadratic step-wise regression analysis was then performed to determine if quadratic correction equations provide better estimates of the temperature/humidity effect on exhaust emission levels. Equations generated for the individual vehicles were of the form

$$E = K + a_1 \Delta T + a_2 \Delta H + a_3 \Delta T^2 + a_4 \Delta H^2 + a_5 \Delta TH$$

where;

E, a_1, ΔT, a_2, and ΔH are defined as for the linear regression form and

K = A constant term for the particular equation.

a_3 = Regression coefficient for the ΔT^2 term.

ΔT^2 = $(T-\bar{T})^2$; i.e., test temperature minus the mean temperature, all squared.

a_4 = Regression coefficient for the ΔH^2 term.

ΔH^2 = $(H-\bar{H})^2$; i.e., test humidity minus the mean humidity all squared.

a_5 = Regression coefficient for the ΔTH term.

$\Delta TH = \Delta T \cdot \Delta H = (T-\bar{T})(H-\bar{H})$; i.e., the product of the test temperature minus the mean temperature and test humidity minus the mean humidity.

The results of the quadratic regression analysis are shown in Tables D-1 through D-6. The order in which the variables appear in the regression equations is again the order in which they were introduced in the step-wise regression process. That is, they are ordered by the values of their simple correlations with the emissions.

In the case of the quadratic regressions, there is no simple transformation for correcting to a different standard T_s and H_s. A program for the purpose of obtaining better estimates of the relationships could easily be designed, however, about a specified standard for T and H.

3.2 DISCUSSION OF RESULTS

Examination of the regression equations and the multiple correlation values indicates that each type of exhaust emission must be considered individually. Additionally, each vehicle appears to react differently to the influences of temperature and humidity, but the effect, if real, is somewhat masked by the inconsistency displayed by some vehicles.

Phase II (duplicate round of testing) data are considered to be more significant than the Phase I data (initial round) for the following reasons:

- Carburetor choke systems were set more precisely and checked for optimum operation prior to second-round testing.

- Minor tune-up items found to be slightly out of specification during the mid-test inspection were corrected and the readjustments maintained their settings better during second-round testing.

- Test procedures were performed more consistently due to familiarization with the routines, apparatus, and vehicles.

The regression results indicate that the effect of temperature and humidity on NO and NO_x values can be estimated reasonably well, as reflected by the high degree of correlation between those emissions and the independent variables. For CO values (both concentration and mass values), the regression equations yield a fair estimate of the effects of temperature and humidity. The regression equations describing the effect of the two variables on HC emissions (both concentration and mass values) indicate the regression estimates not to be significantly better than use of the mean value. These summary results will be clearly demonstrated below in the discussions of the composite vehicle analysis and correction factors.

3.2.1 Correlation of Nitric Oxide (ppm) with the Independent Variables

Values for the coefficient of determination, r^2, ranged from 0.621 to 0.912 for the linear regression equations relating the NO (ppm) to temperature and humidity (except for the Porsche for which the value was 0.242 in Phase I and 0.489 in Phase II). Except for the one vehicle, the regression estimates were significantly better than use of the mean value.

Values for r^2 ranged from 0.610 to 0.941 for the quadratic regression equations relating NO (ppm) to temperature and humidity (except for the Porsche which yielded 0.301 in Phase I). Generally speaking, the quadratic r^2-values are somewhat higher than the equivalent r^2-values for the linear equations and are judged very good.

3.2.2 Correlation of Oxides of Nitrogen (grams/mile) with the Independent Variables

Similarly, NO_x mass emission data showed a satisfactory correlation with temperature and humidity, as described by either the linear or quadratic regression equations. Values for r^2 ranged from 0.512 to 0.872 (American automobiles only) based on linear regression equations. The foreign vehicles did not correlate well in the linear regression computations, where the values ranged from 0.041 to 0.600.

Quadratic regression equations provided a satisfactory description of the relationship between NO_x mass emission data and temperature and humidity (for American vehicles). Values of r^2 (for American vehicles) ranged from 0.602 to 0.920. The foreign vehicles showed a fair correlation between NO_x mass emissions and the independent variables as indicated by r^2-values of 0.199 to 0.686 in the quadratic regression analysis.

3.2.3 Correlation of Carbon Monoxide (%) with the Independent Variables

The linear regression analysis yielded r^2-values of CO (%) versus the independent variables which reflect that the regression explains a very variable amount of the variance. The r^2-values ranged all the way from 0.082 to 0.728 (all vehicles considered).

The quadratic regression equations were slightly more effective in describing the relationships involved. The values of r^2 ranged from 0.248 to 0.812 (all vehicles considered). Only in one-half of the regression equations did an r^2-value above 0.500 result. Therefore, these regression equations are only partially successful in explaining the correlation between percent CO and the two independent variables.

3.2.4 Correlation of Carbon Monoxide (grams/mile) with the Independent Variables

The linear regression analysis yielded r^2-values of CO (grams/mile) versus the two independent variables which again reflect that the amount of variance explained by the regression is highly variable. The r^2-values ranged from 0.057 to 0.749 (all vehicles considered).

The quadratic regression equations were slightly more effective in describing the relationships involved. The values of r^2 ranged from 0.103 to 0.887 (all vehicles considered). In seven of sixteen cases the regression equations yield an r^2-value above 0.500. Therefore, the correlation between the emission and the independent variables is considered to be moderate and these regression equations are only partially successful in explaining the effect of temperature and humidity on the emission measurement.

3.2.5 Correlation of Unburned Hydrocarbons (ppm) with the Independent Variables

Neither linear nor quadratic regression analyses yielded r^2-values that indicate satisfactory correlation of the emission HC (ppm) with the independent variables. Values of r^2 ranged from 0.088 to 0.597 in the linear regression analysis. For the quadratic regression analysis, r^2-values ranged from 0.114 to 0.689. In either case, most of the r^2-values were less than 0.500.

3.2.6 Correlation of Unburned Hydrocarbons (grams/mile) with the Independent Variables

Again, the linear and quadratic regression analyses yielded equations that were inadequate for estimating HC as a function of temperature and humidity.

Values of r^2 in the linear regression analysis ranged from 0.037 to 0.592. For the quadratic regression analysis, values of r^2 ranged from 0.047 to 0.664. In only a few cases did the r^2-value exceed 0.500.

3.3 COMPOSITE VEHICLE ANALYSIS

Examination of the emission data and regression equations, both linear and quadratic, for the individual vehicles indicates a great deal of variability. In particular, the foreign vehicles yielded results considerably different from those of the American-made vehicles. It was therefore concluded that any attempt to create a composite vehicle would have to be based on the American vehicles. Further, since the primary interest here is on the values of the regression coefficients, the variance was minimized by inputting to the computer the deviations from the mean for each vehicle.

As discussed above, the linear regression equation for a given vehicle is of the form

$$E' = \bar{E} + a_1 \Delta T + a_2 \Delta H,$$

where E' = the estimated emission value

$\bar{E}$ = the mean emission value

$\Delta T = T - \bar{T}$

$\Delta H = H - \bar{H}$

a_1, a_2 = regression coefficients.

The objective, however, was to determine the feasibility of obtaining correction factors to be applied to emission measurements to correct them to a standard temperature and humidity. The input data to the composite vehicle regression analysis were thus of the form $\Delta E = E_m - \bar{E}$, where E_m

was a measured value for a given vehicle and $\bar{E}$ was the mean for that vehicle. Since the mean of the ΔE is zero for each vehicle, it is zero for the set of vehicles. As a consequence, the desired correction factors are given by the estimate

$$\Delta E' = a_1 \Delta T + a_2 \Delta H,$$

where $\Delta E'$ is the correction, a_1 and a_2 are the composite vehicle regression coefficients, and ΔT and ΔH are the deviations from 80.6°F and 74 grains of water per pound of dry air, respectively (approximately 48% relative humidity at 80.6°F).

Thus, if E_m (T,H) is the measured emission value at temperature T and humidity H, its value at $T_s = 80.6$ and $H_s = 74$ would be estimated by

$$E' (T_s, H_s) = E_m (T, H) - a_1 \Delta T - a_2 \Delta H.$$

A similar correction could be obtained from the quadratic regression analysis of the composite vehicle, but the slight gain in error reduction is outweighed by the increase in computational complexity. The composite vehicle regression equations, Tables 3.1 and 3.2, and the summary in Table 3.3 demonstrate clearly, for the composite vehicle, that the amount of the regression explained by a linear relationship is just slightly less than that explained by the quadratic. Examination of the data in Table 3.3 permits some general conclusions. The reliability of the Phase II data is verified to be better than that of the Phase I data as already discussed. The square of the multiple correlation coefficient (r^2), sometimes called the coefficient of determination, is a measure of the strength of the relationship between the dependent variable, E, and the independent variables, T and H. For example, from Table 3.3 one finds 83.9% of the measured NO

Table 3.1

Linear Regression Equations
for the Composite Vehicle
(Vehicles 1 through 5)

Linear Regression Equations	S_e	r	r^2
PHASE I			
HC (ppm) = 427.6 + 0.3022 ΔH - 0.7043 ΔT	59.43	0.192	0.037
CO (%) = 1.17 - 0.0089 ΔT + 0.0008 ΔH	0.154	0.537	0.288
NO (ppm) = 1599. - 6.2621 ΔH + 0.0273 ΔT	158.5	0.867	0.752
HC (gms/mile) = 5.98 - 0.0308 ΔT + 0.0008 ΔH	1.918	0.188	0.035
CO (gms/mile) = 42.52 - 0.5252 ΔT + 0.0156 ΔH	13.349	0.424	0.179
NO_x (gms/mile) = 7.95 - 0.0356 ΔH + 0.0442 ΔT	1.127	0.772	0.595
PHASE II			
HC (ppm) = 353.4 - 1.1156 ΔT + 0.2973 ΔH	26.39	0.453	0.207
CO (%) = 1.10 - 0.0120 ΔT + 0.0016 ΔH	0.127	0.716	0.513
NO (ppm) = 1486. - 5.9718 ΔH + 4.1332 ΔT	104.3	0.916	0.839
HC (gms/mile) = 5.04 - 0.0274 ΔT + 0.0016 ΔH	0.556	0.489	0.239
CO (gms/mile) = 38.24 - 0.6020 ΔT + 0.0331 ΔH	7.779	0.664	0.440
NO_x (gms/mile) = 6.65 - 0.0318 ΔH + 0.0337 ΔT	0.741	0.857	0.734

Table 3.2

Quadratic Regression Equations
for the Composite Vehicles
(Vehicles 1 through 5)

	Quadratic Regression Equations	S_e	r	r^2
PHASE I				
HC (ppm) = $\overline{HC}$ (ppm)	+ 11.653 + 0.1897 ΔH - 0.8025 ΔT - 0.1066 ΔT^2 + 0.0249 ΔTH - 0.0011 ΔH^2	59.038	0.281	0.079
CO (%) = $\overline{CO}$ (%)	+ 0.042 - 0.0096 ΔT - 0.0003 ΔT^2 + 0.0006 ΔH + 0.0000 ΔTH - 0.0000 ΔH^2	0.151	0.584	0.341
NO (ppm) = $\overline{NO}$ (ppm)	- 44.390 - 6.8002 ΔH + 0.0356 ΔH^2 - 0.1077 ΔTH - 1.3512 ΔT + 0.0441 ΔT^2	151.64	0.883	0.780
HC (gm/mi) = $\overline{HC}$ (gm/mi)	+ 0.277 - 0.0304 ΔT - 0.0034 ΔT^2 + 0.0009 ΔTH - 0.0048 ΔH - 0.0000 ΔH^2	1.900	0.288	0.083
CO (gm/mi) = $\overline{CO}$ (gm/mi)	+ 1.537 - 0.4968 ΔT - 0.0174 ΔT^2 + 0.0063 ΔTH - 0.0003 ΔH^2 - 0.0134 ΔH	13.388	0.448	0.201
NO_x (gm/mi) = $\overline{NO_x}$ (gm/mi)	- 0.011 - 0.0394 ΔH + 0.0383 ΔT + 0.0001 ΔH^2 - 0.0013 ΔT^2 - 0.0000 ΔTH	1.107	0.789	0.622
PHASE II				
HC (ppm) = $\overline{HC}$ (ppm)	- 4.777 - 1.3581 ΔT + 0.3899 ΔH - 0.0270 ΔTH + 0.0491 ΔT^2 + 0.0024 ΔH^2	25.938	0.506	0.256
CO (%) = $\overline{CO}$ (%)	- 0.025 - 0.0109 ΔT + 0.0000 ΔH^2 + 0.0008 ΔH + 0.0000 ΔTH - 0.0000 ΔT^2	0.121	0.754	0.568
NO (ppm) = $\overline{NO}$ (ppm)	- 5.928 - 5.6785 ΔH + 2.9588 ΔT - 0.0881 ΔTH + 0.0085 ΔH^2 + 0.0906 ΔT^2	103.891	0.919	0.845
HC (gm/mi) = $\overline{HC}$ (gm/mi)	- 0.166 - 0.0230 ΔT + 0.0014 ΔT^2 + 0.0028 ΔH - 0.0001 ΔTH - 0.0000 ΔH^2	0.534	0.564	0.318
CO (gm/mi) = $\overline{CO}$ (gm/mi)	- 1.892 - 0.4684 ΔT + 0.0048 ΔTH + 0.0067 ΔT^2 - 0.0002 ΔH^2 + 0.0071 ΔH	7.540	0.700	0.490
NO_x (gm/mi) = $\overline{NO_x}$ (gm/mi)	- 0.273 - 0.0329 ΔH + 0.0302 ΔT + 0.0001 ΔH^2 - 0.0005 ΔTH + 0.0001 ΔT^2	0.720	0.870	0.757

Table 3.3

Composite Vehicle Regression Equations
Correlation Comparison

Emission	Analysis: Linear r^2	Analysis: Quadratic r^2	Improvement
PHASE I			
HC (ppm)	0.037	0.079	0.042
CO (%)	0.288	0.341	0.053
NO (ppm)	0.752	0.780	0.028
HC (gms/mile)	0.035	0.083	0.048
CO (gms/mile)	0.179	0.201	0.022
NO_x (gms/mile)	0.595	0.622	0.027
PHASE II			
HC (ppm)	0.207	0.256	0.049
CO (%)	0.513	0.568	0.055
NO (ppm)	0.839	0.845	0.006
HC (gms/mile)	0.239	0.318	0.079
CO (gms/mile)	0.440	0.490	0.050
NO_x (gms/mile)	0.734	0.757	0.023

concentrations for the Phase II composite vehicle to be explained by the relationship of the linear regression plane. Note further, for that case, that the quadratic fit yields an absolute improvement of just 0.6%. In general, relative to ΔT and ΔH, there is a weak relationship for hydrocarbon emissions, a moderate relationship for CO emissions, and a rather strong relationship for the oxides of nitrogen.

Correction factors based on the Phase I and Phase II composite vehicle regression analyses can be determined from the graphs of Appendix E, Figures E-1 through E-16. To illustrate how they would be used, if they were based on an adequate data sample, consider Figure 3.1. Suppose NO (ppm) is measured on a day when the ambient temperature is 90.6°F and the humidity is at a level of 154 grains of water per pound of dry air. Then,

$$\Delta T = 90.6 - 80.6 = 10^{\circ}F$$

$$\Delta H = 154 - 74 = 80 \text{ grains } H_2O/1b \text{ dry air.}$$

Entering Figure 3.1 with those values of ΔT and ΔH, one finds that about 418 ppm must be added to the measured value to reduce it to a value at the standard of T = 80.6 and H = 74.

The relative importance of temperature and humidity is easily obtained from Figure 3.1. For example, the total excursion of the correction factor for ΔH = constant and ΔT ranging from +15 to -20 is just 140 ppm of NO. On the other hand, if ΔT = constant, then the total excursion of the correction factor where ΔH ranges from -60 to +100 is about 960 ppm of NO. The sensitivity of each emission to ΔT and ΔH is thus indicated by both the regression equations and the calibration charts in Appendix E.

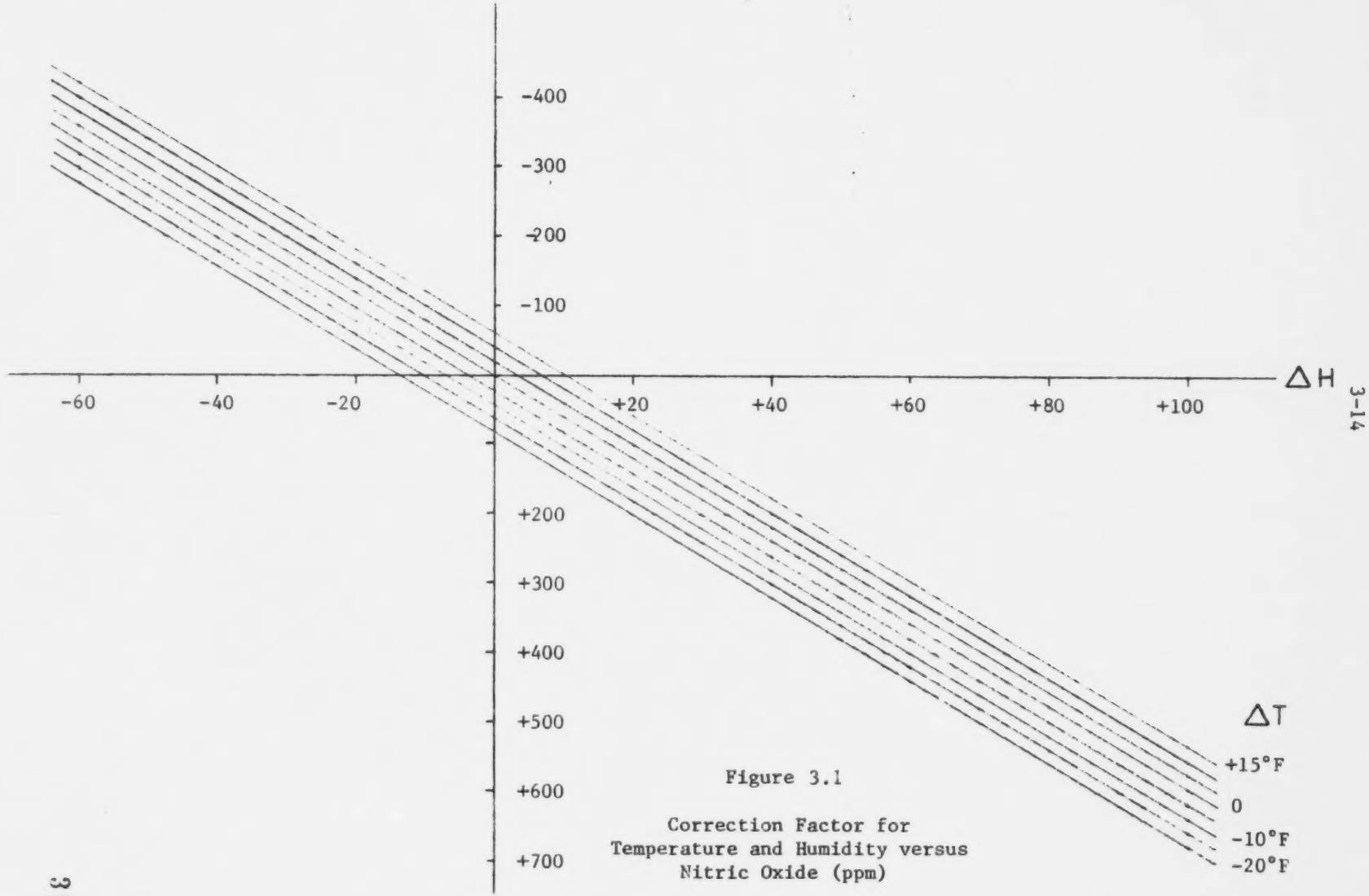

Figure 3.1

Correction Factor for
Temperature and Humidity versus
Nitric Oxide (ppm)

Phase II

It must be clearly recognized, of course, that judgment must be exercised in applying these correction factors because they are based on a small sample of vehicles. The results of the regression analyses show quite clearly that additional work with a larger vehicle sample is desirable.

The results have established, however, the feasibility of developing factors for the purpose of correcting exhaust emission measurements to standard conditions of temperature and humidity. It is recommended, therefore, that additional work be accomplished with a larger vehicle sample to establish these factors with a greater degree of confidence. The initial phase of any further effort should consist of preliminary exhaust emission measurements on a larger-than-desired fleet of vehicles in order to eliminate those vehicles whose exhaust content is variable beyond a reasonable level. Further, representation of foreign vehicles must be increased in order to include them in the composite vehicle regression or to determine a separate set of calibration charts.

APPENDIX A

Determination of Mass Emissions

Scott Research Labs., Inc.
Project #2846

April 24, 1970

DETERMINATION OF MASS EMISSIONS

$$\text{Emissions (grams/mile)} = C \cdot V \cdot T \cdot d$$

where C = Concentration of emissions measured in ppm

V = Specific volume flow rate of variable dilution system*

T = Time in travel one mile averaged over the nine cycles

d = Density of particular emission value in grams per cubic foot*

* These values are stated at standard conditions of 68°F and 29.92 inches of Hg pressure.

Sample Calculation

Suppose C = 230 ppm unburned hydrocarbons

V = 322 SCFM (at 68°F and 29.92 in. of Hg)

T = 2.755 minutes per mile

d = 16.33 grams per cubic foot (at 68°F and 29.92 in. of Hg).

Then, $E = (.000230)(322\ ft^3/min.)(2.755\ min/mile)(16.33\ grams/ft^3)$

$= 3.33$ grams/mile unburned hydrocarbons

C ... Values obtained by analyzing bag samples of diluted exhaust gas for concentration of each emission.

V ... Volume flow rate of variable dilution system measured for each individual test and corrected to 68°F and 29.92 inches of Hg.

T ... Time-distance constant for all vehicles travelling nine cycles of 0.833 miles per cycle, in 137 seconds per cycle. Additional 20 seconds for first cycle idle mode and 5 seconds for system operating time after completion of ninth cycle added in to total time.

d ... Densities of respective pollutants as detailed below:

d for HC = 16.33 grams/cubic foot
d for CO = 33.11 grams/cubic foot
d for NO_x = 54.16 grams/cubic foot

APPENDIX B

Test Data

Scott Research Laboratories, Inc.
Project #2846

April 24, 1970

Table B-1
Vehicle Number 1

Phase 1

			7-Mode Cycle Weighted Emissions			Mass Emissions - Gms/Mile			
Date	T Dry	GR/LB	HC ppm	CO%	NO ppm	HC	CO	NO_x	Run No.
12-30-69	59	20	432	1.16	1947	5.99	43.8	9.20	3835
12-10-69	59	40	501	1.06	1682	5.36	38.9	8.30	3768
11-26-69	59	60	453	1.17	1748	5.39	42.6	6.45	3718
11-19-69	71	20	494	1.00	2130	6.34	27.8	13.7	3694
11-13-69	71	40	513	1.02	1933	5.88	23.7	12.6	3686
11-10-69	71	60	498	1.21	1888	6.42	30.1	8.81	3680
12-9-69	71	80	373	1.17	1318	5.13	40.5	7.48	3760
12-3-69	83	20	517	0.91	2032	6.06	30.8	13.0	3741
12-2-69	83	40	492	0.95	1914	5.60	34.6	10.4	3734
11-21-69	83	60	412	0.89	1454	4.90	32.5	8.54	3702
11-25-69	83	80	504	0.96	1582	5.62	36.2	7.36	3710
12-5-69	83	100	480	1.00	1269	4.87	35.2	6.19	3748
11-28-69	83	120	506	1.07	1338	5.94	39.6	5.91	3726
12-11-69	83	140	506	0.87	1378	5.43	33.5	6.76	3776
12-26-69	95	40	577	1.09	1868	5.44	35.3	10.5	3821
12-17-69	95	60	414	0.84	1618	6.12	30.8	8.08	3796
12-16-69	95	80	521	0.99	1678	7.69	32.7	10.5	3789
12-8-69	95	100	593	0.86	1417	5.52	31.0	7.79	3757
12-12-69	95	140	537	0.83	1344	5.65	29.6	6.11	3782
12-18-69	95	180	553	0.79	1015	5.95	25.7	4.98	3903

Table B-2

Vehicle Number 2

Phase I

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
12-30-69	59	20	461	1.04	2202	6.53	37.5	8.75	3836
12-10-69	59	40	508	0.98	2156	5.71	27.3	8.11	3769
11-26-69	59	60	503	1.06	2024	5.21	27.1	6.91	3719
11-19-69	71	20	582	1.00	2158	7.33	26.0	11.2	3695
11-13-69	71	40	567	1.14	1812	6.50	27.3	10.8	3687
11-10-69	71	60	437	1.40	1670	6.10	48.2	4.89	3769
12-19-69	71	80	411	1.03	1719	4.98	28.4	7.89	3763
12-3-69	83	20	446	0.95	2214	4.29	25.1	8.57	3742
12-2-69	83	40	467	0.94	2157	5.08	25.1	8.96	3735
11-21-69	83	60	636	1.28	1713	8.32	34.9	9.26	3703
11-25-69	83	80	480	0.92	1628	5.12	27.0	6.72	3711
12-5-69	83	100	689	1.12	1552	7.79	31.8	7.67	3749
12-1-69	83	120	629	1.24	1473	7.28	35.7	7.44	3727
12-11-69	83	140	519	0.96	1410	4.90	26.3	5.89	3775
12-26-69	95	40	466	1.01	1980	5.00	24.0	9.13	3822
12-17-69	95	60	361	0.85	1974	4.90	27.2	7.89	3797
12-16-69	95	80	391	0.87	1576	5.45	33.6	6.98	3790
12-7-69	95	100	462	0.95	1318	4.85	35.1	6.73	3758
12-15-69	95	140	460	1.19	1194	5.82	39.3	4.99	3783
12-18-69	95	180	472	0.98	1333	5.29	29.0	5.76	3804

Table B-3

Vehicle Number 3

Phase I

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
12-30-69	59	20	306	1.24	1520	4.63	50.0	8.04	3837
12-10-69	59	40	327	1.01	1793	5.30	43.3	10.1	3770
11-28-69	59	60	251	0.56	1591	3.32	21.8	8.49	3721
11-20-69	71	20	323	0.98	1674	4.83	33.5	8.56	3696
11-17-69	71	40	316	1.18	1521	5.51	40.8	8.28	3688
11-10-69	71	60	330	1.31	1467	4.81	46.2	6.70	3681
12-9-69	71	80	326	0.93	1443	4.71	37.9	7.72	3761
12-27-69	83	20	339	0.76	2132	4.17	31.3	11.1	3829
12-2-69	83	40	345	0.74	1826	4.81	25.4	8.71	3736
11-24-69	83	60	293	0.59	1608	3.44	23.7	8.71	3704
11-25-69	83	80	345	0.89	1510	4.61	28.8	8.04	3712
12-4-69	83	100	280	0.66	1262	4.44	26.5	7.60	3743
12-1-69	83	120	356	0.92	1094	5.02	34.2	7.58	3727
12-11-69	83	140	338	0.88	1210	4.94	33.6	7.44	3777
12-26-69	95	40	307	0.63	1702	4.38	21.9	11.0	3823
12-17-69	95	60	258	0.56	1782	4.21	18.4	10.9	3798
12-16-69	95	80	300	0.58	1264	4.41	23.7	8.03	3791
12-5-69	95	100	362	0.72	1343	5.05	26.9	9.43	3750
12-15-69	95	140	385	0.77	879	5.31	29.0	5.88	3784
12-18-69	95	180	323	0.75	1301	5.23	25.8	6.42	3805

Table B-4

Vehicle Number 4

Phase I

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
12-30-69	59	20	330	1.47	1420	5.44	65.7	6.90	3838
12-11-69	59	40	411	1.69	1256	7.09	84.4	5.73	3771
11-28-69	59	60	324	1.55	1218	6.48	66.8	5.62	3721
11-20-69	71	20	344	1.92	1455	6.44	68.3	6.43	3697
11-17-69	71	40	372	1.79	1296	6.64	67.7	6.17	3689
11-11-69	71	60	266	1.30	1183	4.16	36.3	5.61	3682
12-9-69	71	80	364	1.57	1224	6.34	65.4	5.92	3762
12-29-69	83	20	350	1.21	1547	4.80	43.5	8.31	3830
12-3-69	83	40	373	1.21	1361	5.41	43.3	6.76	3737
11-24-69	83	60	316	1.38	1221	5.44	55.5	6.99	3705
11-25-69	83	80	286	1.36	929	5.20	47.5	6.00	3713
12-4-69	83	100	399	1.45	1020	6.06	48.5	6.38	3744
12-2-69	83	120	412	1.43	821	5.68	51.6	4.64	3729
12-12-69	83	140	369	1.59	678	6.79	63.4	4.41	3798
12-26-69	95	40	372	1.14	1404	5.16	37.3	8.47	3824
12-18-69	95	60	250	1.10	1211	5.18	38.9	7.04	3799
12-16-69	95	80	358	1.07	1203	5.60	34.6	6.48	3793
12-5-69	95	100	378	1.01	1089	3.58	47.9	6.56	3751
12-15-69	95	140	412	1.23	753	6.43	36.6	5.02	3785
12-19-69	95	180	383	1.31	702	6.41	42.2	4.51	3806

Table B-5

Vehicle Number 5

Phase I

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
12-30-69	59	20	449	1.54	2489	5.26	50.0	10.6	3839
12-11-69	59	40	539	1.90	1939	6.82	70.4	8.14	3772
11-28-69	59	60	565	1.66	2241	12.8	98.2	7.99	3722
11-20-69	71	20	503	1.58	2506	20.9	158.7	11.5	3698
11-17-69	71	40	573	1.70	2559	10.4	72.4	11.8	3690
11-11-69	71	60	378	1.42	2021	5.12	46.6	80.1	3683
12-10-69	71	80	454	1.56	1672	6.29	55.0	7.29	3764
12-29-69	83	20	406	1.50	2128	5.23	46.1	9.65	3831
12-2-69	83	40	559	1.72	2421	12.2	83.1	11.1	3738
11-24-69	83	60	430	1.59	2305	7.20	76.5	11.2	3706
11-26-69	83	80	532	1.70	1865	10.9	76.5	8.68	3714
12-4-69	83	100	500	1.90	2151	5.98	53.9	8.07	3745
12-2-69	83	120	622	1.88	1656	11.7	78.8	8.50	3730
12-12-69	83	140	453	1.80	1354	5.94	51.0	5.68	3779
12-26-69	95	40	392	1.43	2137	4.54	37.2	10.5	3825
12-18-69	95	60	440	1.54	1986	5.53	47.5	8.89	3800
12-16-69	95	80	360	1.40	1650	4.91	41.6	8.20	3793
12-5-69	95	100	429	1.56	1601	5.12	45.3	8.08	3752
12-15-69	95	140	446	1.60	1393	5.11	42.4	6.26	3786
12-19-69	95	180	424	1.77	1152	6.85	62.9	4.99	3807

Table B-6

Vehicle Number 6

Phase I

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
12-30-69	59	20	276	1.86	1651	3.04	48.0	3.76	3840
12-11-69	59	40	318	1.73	1338	3.63	56.0	3.92	3773
11-28-69	59	60	275	1.32	742	3.22	46.7	3.03	3723
11-20-69	71	20	261	1.71	1413	2.94	52.1	4.44	3699
11-18-69	71	40	225	2.26	1195	3.22	66.4	3.22	3691
11-7-69	71	60	319	2.43	1131	3.55	64.1	2.46	3678
12-10-69	71	80	304	2.54	1044	3.37	70.7	2.53	3765
12-29-69	83	20	272	2.36	1158	2.84	58.2	3.10	3832
12-3-69	83	40	314	2.70	1360	4.36	87.0	2.99	3739
11-24-69	83	60	271	1.97	1080	3.07	57.5	4.37	3707
11-26-69	83	80	257	2.13	869	3.28	76.2	3.68	3715
12-4-69	83	100	266	2.33	1014	2.73	69.8	3.40	3746
12-2-69	83	120	315	2.53	864	3.06	65.0	3.58	3731
12-12-69	83	140	-	-	-	3.31	72.5	2.91	3780
12-27-69	95	40	300	2.62	1124	3.32	63.0	2.18	3826
12-18-69	95	60	227	2.26	1036	2.89	63.0	3.05	3801
12-16-69	95	80	314	2.66	975	3.10	65.8	2.10	3794
12-9-69	95	100	282	2.66	696	3.16	81.4	2.98	3759
12-15-69	95	140	297	2.36	742	3.10	64.0	2.46	3787
12-19-69	95	180	325	3.13	456	3.62	84.4	1.62	3808

Table B-7

Vehicle Number 7

Phase 1

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
12-30-68	59	20	1046	2.30	2033	7.51	29.6	8.26	3841
12-11-68	59	40	1032	2.36	1617	7.86	31.0	6.55	3774
11-28-69	59	60	894	2.32	1132	6.22	30.4	5.79	3724
11-21-69	71	20	718	2.41	1639	6.27	33.1	6.99	3700
11-19-69	71	40	830	2.19	1910	6.35	26.0	7.37	3694
11-12-69	71	60	792	2.30	1958	6.21	30.8	6.29	3684
12-10-69	71	80	1004	2.68	1380	7.78	36.2	6.26	3766
12-29-69	83	20	949	2.58	1811	6.75	37.2	7.32	3833
12-3-69	83	40	1171	3.16	1690	6.96	34.4	7.17	3740
11-25-69	83	60	1031	2.89	1495	7.72	36.8	6.07	3708
11-26-69	83	80	891	2.15	1419	5.88	36.2	7.51	3716
12-4-69	83	100	1054	2.52	1631	6.57	34.3	6.56	3747
12-2-69	83	120	959	2.84	1253	4.07	6.94	9.34	3732
12-12-69	83	140	969	2.80	1250	6.41	37.3	5.87	3781
12-27-69	95	40	873	2.72	1871	5.76	38.6	7.19	3826
12-18-69	95	60	867	2.73	1532	6.32	33.2	6.80	3802
12-22-69	95	80	924	2.36	1431	5.38	32.5	7.34	3815
12-8-69	95	100	952	2.96	1255	7.13	45.6	6.94	3754
12-15-69	95	140	902	3.12	1064	6.55	37.2	5.21	3788
12-19-69	95	180	1125	2.99	1066	7.37	35.7	5.42	3809

Table B-8

Vehicle Number 8

Phase 1

			7-Mode Cycle Weighted Emissions			Mass Emissions - Gms/Mile			
Date	T Dry	GR/LB	HC ppm	CO%	NO ppm	HC	CO	NO_x	Run No.
12-30-69	59	20	806	4.88	350	8.22	89.1	1.48	3834
12-31-69	59	40	818	5.58	259	9.30	92.2	1.27	3842
11-28-69	59	60	1061	1.84	858	7.15	33.5	2.76	3725
11-21-69	71	20	860	1.98	801	7.15	38.8	2.93	3701
11-19-69	71	40	876	1.74	791	7.13	33.1	3.20	3692
11-12-69	71	60	953	2.02	720	7.87	46.7	2.39	3685
12-10-69	71	80	1329	2.43	600	10.4	56.7	2.15	3767
12-29-69	83	20	664	4.66	288	7.80	87.1	1.32	3828
12-31-69	83	40	691	5.49	315	8.24	97.3	1.96	3843
11-25-69	83	60	951	2.79	650	7.64	53.4	3.64	3709
11-26-69	83	80	912	2.53	592	7.00	43.8	2.39	3717
1-2-70	83	100	717	5.29	182	7.18	92.3	0.81	3844
12-2-69	83	120	1190	2.86	354	8.67	68.6	3.04	3733
12-23-69	83	140	635	5.46	243	9.16	94.8	1.02	3819
12-20-69	95	40	650	3.90	394	9.04	79.6	1.08	3811
12-19-69	95	60	634	4.16	348	6.45	81.8	0.64	3810
12-22-69	95	80	791	4.67	224	7.26	76.2	1.48	3814
12-8-69	95	100	1137	2.49	497	8.57	54.5	2.25	3756
12-22-69	95	140	795	4.85	229	8.01	87.7	0.42	3816
12-23-69	95	180	901	5.22	94	9.51	103.9	0.81	3817

Table R-9

Vehicle Number 1

Phase 2

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
2-3-70	59	20	395	1.20	1499	5.10	35.3	7.62	3982
1-13-70	59	40	371	1.12	1414	4.96	43.4	6.81	3881
1-23-70	59	60	401	1.32	1448	6.21	49.1	6.54	3940
2-2-70	71	20	348	1.26	1539	5.10	48.0	6.92	3975
1-5-70	71	40	410	1.14	1491	4.99	35.8	6.90	3847
2-3-70	71	60	426	1.33	1327	5.64	40.4	6.48	3990
1-19-70	71	80	388	1.15	1177	4.87	46.7	5.39	3909
1-6-70	83	20	365	1.14	1595	4.47	29.6	7.42	3852
1-30-70	83	40	342	1.26	1551	*	*	*	3966
1-21-70	83	60	392	0.98	1253	5.64	50.3	5.26	3923
1-14-70	83	80	349	1.01	1105	4.61	33.5	6.06	3888
1-12-70	83	100	349	0.94	1117	3.79	21.5	4.24	3874
1-15-70	83	120	455	1.23	1175	4.85	29.9	3.39	3897
1-7-70	83	140	436	1.22	914	5.46	36.6	3.35	3860
1-29-70	95	40	404	0.99	1581	5.04	40.4	7.51	3958
1-22-70	95	60	426	0.88	1385	5.36	25.5	7.04	3932
1-8-70	95	80	440	1.17	1193	6.40	54.0	4.69	3867
1-20-70	95	100	378	1.05	1083	4.91	36.1	5.34	3915
2-5-70	95	140	405	1.27	846	5.03	37.9	4.62	3999
1-27-70	95	180	400	1.26	927	5.13	38.0	4.94	3949

* System or vehicle malfunction - data not valid.

Table B-10

Vehicle Number 2

Phase 2

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
2-3-70	59	20	335	1.56	1582	4.92	52.9	8.21	3983
1-13-70	59	40	350	1.46	1427	4.39	47.2	5.92	3882
1-23-70	59	60	375	1.39	1450	5.67	44.8	5.60	3941
2-2-70	71	20	321	1.37	1589	4.66	50.3	6.69	3976
1-2-70	71	40	399	1.34	1551	4.94	41.2	6.60	3845
2-3-70	71	60	352	1.33	1515	5.10	42.4	6.46	3991
1-16-70	71	80	384	1.45	1312	4.87	44.7	5.15	3906
1-6-70	83	20	366	1.28	1728	4.65	33.8	7.12	3853
1-30-70	83	40	289	1.43	1642	4.43	36.5	6.37	3967
1-21-70	83	60	362	1.16	1330	5.08	34.1	6.44	3924
1-14-70	83	80	333	1.40	1304	4.84	36.2	4.26	3890
1-12-70	83	100	309	1.36	1157	4.81	48.2	4.94	3875
1-15-70	83	120	377	1.27	1091	4.68	33.6	4.61	3898
1-7-70	83	140	418	1.48	1155	4.44	39.1	3.94	3861
1-29-70	95	40	331	1.09	1625	4.59	32.2	7.26	3959
1-22-70	95	60	356	1.03	1471	5.53	30.8	6.80	3933
1-9-70	95	80	354	1.19	1299	4.86	41.0	5.42	3868
1-20-70	95	100	346	1.15	1283	4.58	36.2	5.59	3916
2-5-70	95	140	357	1.34	897	4.80	35.9	4.38	4000
1-28-70	95	180	351	1.35	888	4.65	41.4	3.84	3950

Table B-11

Vehicle Number 3

Phase 2

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
2-3-70	59	20	340	1.33	1763	6.08	61.9	8.31	3984
1-13-70	59	40	353	1.23	1653	5.72	53.6	7.74	3883
1-26-70	59	60	366	1.11	1498	6.13	42.9	7.89	3942
2-2-70	71	20	314	1.13	1694	4.96	37.6	8.33	3977
1-5-70	71	40	337	1.13	1737	5.58	35.0	8.89	3848
2-4-70	71	60	332	1.27	1533	5.52	42.8	5.82	3993
1-19-70	71	80	348	1.06	1378	4.78	34.4	5.58	3910
1-7-70	83	20	357	0.72	1872	4.56	27.8	10.6	3856
1-30-70	83	40	262	0.78	1823	4.24	27.8	8.45	3968
1-21-70	83	60	327	0.63	1657	4.82	18.1	9.34	3925
1-14-70	83	80	338	0.76	1731	5.41	26.7	9.08	3891
1-12-70	83	100	324	0.92	1345	4.81	28.4	7.36	3876
1-15-70	83	120	358	0.86	1404	5.72	32.0	6.61	3899
1-8-70	83	140	338	0.85	1053	4.79	26.4	5.86	3862
1-29-70	95	40	298	0.61	1696	4.38	17.2	9.84	3960
1-22-70	95	60	335	0.69	1863	5.09	22.0	9.28	3934
1-9-70	95	80	321	0.72	1543	4.44	25.6	7.17	3869
1-20-70	95	100	322	0.73	1468	4.50	26.9	7.12	3917
2-5-70	95	140	328	0.90	1140	4.67	28.9	5.83	4001
1-28-70	95	180	333	0.96	1077	5.16	24.5	5.20	3951

Table B-12

Vehicle Number 4

Phase 2

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
2-3-70	59	20	320	1.76	1469	6.62	75.2	7.12	3985
1-13-70	59	40	408	1.69	1328	7.88	79.6	5.98	3884
1-26-70	59	60	407	1.74	1333	9.07	85.8	6.08	3943
	71	20		TEST RESULTS VOID					
1-[illegible]-70	71	40	404	1.47	1524	6.04	59.2	8.06	3849
1-30-70	71	60	281	1.31	1559	4.76	37.5	7.65	3969
1-19-70	71	80	349	1.40	1161	5.57	55.0	4.96	3911
1-7-70	83	20	359	1.24	1526	5.97	47.9	8.04	3855
2-4-70	83	40	315	1.65	1232	5.96	55.2	6.02	3995
1-22-70	83	60	302	1.17	1477	5.64	45.2	7.70	3927
1-14-70	83	80	311	1.32	1308	5.45	48.5	6.46	3889
1-12-70	83	100	330	1.28	1122	5.41	50.2	5.56	3877
1-16-70	83	120	364	1.36	1070	5.55	47.9	4.86	3902
1-8-70	83	140	384	1.55	970	6.07	52.7	4.57	3863
1-29-70	95	40	279	0.84	1606	4.65	24.2	9.50	3961
1-23-70	95	60	313	1.00	1503	5.44	38.9	7.77	3936
1-9-70	95	80	316	1.00	1311	4.42	28.7	6.67	3870
1-20-70	95	100	316	1.00	1254	5.00	26.8	6.24	3918
2-6-70	95	140	351	1.25	910	5.84	50.9	3.93	4005
1-28-70	95	180	339	1.43	767	4.89	43.2	3.85	3952

Table B-13

Vehicle Number 5

Phase 2

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
2-3-70	59	20	350	1.03	2103	4.98	47.1	8.01	3986
1-13-70	59	40	382	0.85	1960	4.78	37.1	7.74	3885
1-26-70	59	60	383	0.96	2010	5.04	38.5	7.89	3943
2-2-70	71	20	327	0.65	2278	4.66	30.0	9.97	3979
1-6-70	71	40	369	0.74	2190	4.37	26.2	9.22	3851
2-4-70	71	60	369	1.06	1981	5.08	40.8	6.44	3994
1-19-70	71	80	360	0.81	1929	4.34	25.2	7.39	3912
1-7-70	83	20	360	0.73	2262	4.01	29.5	9.71	3857
1-30-70	83	40	322	0.74	2354	4.05	23.8	9.35	3970
1-22-70	83	60	341	0.87	2051	4.67	33.0	7.74	3928
1-15-70	83	80	323	0.72	1962	3.89	23.4	7.60	3894
1-12-70	83	100	340	0.82	1757	4.47	40.6	6.89	3878
1-16-70	83	120	349	0.72	1673	3.85	21.4	6.21	3903
1-8-70	83	140	373	0.96	1395	4.54	33.8	5.62	3864
1-29-70	95	40	317	0.68	2441	4.10	24.1	10.4	3962
1-23-70	95	60	329	0.65	2170	4.21	22.0	8.89	3936
1-9-70	95	80	318	0.84	1910	4.16	27.2	7.34	3871
1-20-70	95	100	332	0.63	2165	4.06	19.9	6.70	3919
2-6-70	95	140	368	0.86	1331	4.70	30.1	4.97	4006
1-28-70	95	180	353	0.96	1146	4.24	29.8	4.28	3953

Table B-14

Vehicle Number 6

Phase 2

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
02-03-70	59	20	219	2.58	1265	3.28	63.8	2.84	3987
01-13-70	59	40	275	2.09	1391	3.53	53.7	3.27	3886
01-26-70	59	60	271	2.03	1296	3.22	52.9	2.98	3945
02-02-70	71	20	223	1.89	1543	3.59	58.8	3.52	3980
01-02-70	71	40	303	2.63	1156	3.53	60.3	3.27	3846
02-04-70	71	60	250	2.01	1358	3.53	57.4	3.00	3996
01-19-70	71	80	298	2.09	1321	3.65	61.7	2.98	3913
01-07-70	83	20	281	2.72	1276	3.99	77.2	2.84	3858
01-30-70	83	40	226	1.89	1540	2.90	53.4	3.01	3971
01-22-70	83	60	262	2.92	1026	3.52	72.0	2.39	3929
01-15-70	83	80	267	2.95	920	3.20	66.0	2.51	3895
01-12-70	83	100	315	2.52	1023	3.87	65.6	2.14	3879
01-16-70	83	120	279	3.38	735	3.50	74.4	2.12	3904
01-08-70	83	140	322	2.55	855	3.86	57.1	1.86	3865
01-29-70	95	40	246	2.46	1483	3.49	58.6	2.87	3963
01-23-70	95	60	244	3.30	979	3.34	74.2	2.82	3937
01-09-70	95	80	314	2.72	1157	3.99	52.7	4.08	3872
01-21-70	95	100	336	2.86	1068	4.94	77.9	2.59	3926
02-07-70	95	140	307	2.95	828	4.05	67.5	1.68	4007
01-28-70	95	180	281	2.86	678	3.00	65.5	1.20	3954

Table B-15

Vehicle Number 7

Phase 2

			7-Mode Cycle Weighted Emissions			Mass Emissions - Gms/Mile			
Date	T Dry	GR/LB	HC ppm	CO%	NO ppm	HC	CO	NO_x	Run No.
02-03-70	59	20	494	2.87	832	8.48	39.1	3.91	3988
02-04-70	59	40	442	2.64	951	5.76	40.7	4.10	3992
01-26-70	59	60	538	2.66	893	6.54	36.6	3.86	3947
02-02-70	71	20	405	2.01	1147	4.88	33.9	4.45	3974
01-19-70	71	40	451	2.60	961	4.58	29.2	3.70	3908
02-04-70	71	60	528	3.05	897	9.16	42.9	3.83	3998
01-16-70	71	80	408	2.68	784	5.57	32.6	2.55	3907
01-30-70	83	29	413	2.89	929	5.44	39.5	3.70	3973
01-30-70	83	40	368	2.67	843	4.27	33.6	3.49	3965
01-22-70	83	60	431	2.91	821	5.03	40.9	3.45	3930
01-14-70	83	80	462	3.13	679	5.52	32.2	2.53	3892
01-15-70	83	100	384	3.00	716	4.71	35.9	2.94	3893
01-15-70	83	120	343	2.75	607	3.50	28.3	2.98	3900
01-16-70	83	140	419	3.02	668	4.41	31.8	2.96	3901
02-06-70	95	40	399	3.00	936	4.42	41.2	3.96	4003
01-23-70	95	60	473	3.18	836	4.48	49.2	3.16	3938
01-21-70	95	80	380	2.60	845	4.47	34.0	3.61	3921
01-21-70	95	100	436	3.31	650	5.41	40.1	3.23	3920
02-05-70	95	140	442	3.20	506	4.80	34.8	3.73	4002
01-28-70	95	180	427	3.15	598	4.59	40.3	3.09	3955

Table B-16

Vehicle Number 8

Phase 2

Date	T Dry	GR/LB	7-Mode Cycle Weighted Emissions HC ppm	CO%	NO ppm	Mass Emissions - Gms/Mile HC	CO	NO_x	Run No.
02-03-70	59	20	744	4.72	360	9.07	81.5	1.07	3989
01-13-70	59	40	634	4.95	355	7.86	79.4	1.27	3887
01-26-70	59	60	729	4.47	348	9.05	90.5	1.06	3946
02-02-70	71	20	648	5.10	366	9.08	91.2	1.29	3981
01-05-70	71	40	691	5.18	296	7.64	87.4	0.84	3850
02-04-70	71	60	674	5.12	294	9.13	88.2	1.05	3997
01-19-70	71	80	669	5.39	304	8.79	95.5	0.72	3914
01-07-70	83	20	535	4.72	260	6.56	92.2	0.64	3859
01-30-70	83	40	591	5.27	345	8.19	89.3	1.27	3972
01-22-70	83	60	603	5.44	194	6.15	74.2	1.26	3931
01-15-70	83	80	560	5.34	234	7.00	85.0	1.05	3896
01-12-70	83	100	632	5.13	264	8.33	89.4	1.05	3880
01-16-70	83	120	685	5.65	220	8.11	91.2	0.85	3905
01-08-70	83	140	714	5.64	240	7.98	84.9	0.84	3866
01-29-70	95	40	630	5.51	287	7.01	88.4	0.85	3957
01-23-70	95	60	675	5.44	283	7.88	91.1	0.82	3939
01-09-70	95	80	643	5.48	303	5.98	68.6	2.54	3873
01-21-70	95	100	669	4.80	207	7.20	85.3	1.10	3922
02-06-70	95	140	731	5.47	121	8.03	88.9	0.84	4004
01-28-70	95	180	793	5.87	281	9.38	102.2	0.83	3956

APPENDIX C

Linear Regression Equations

By Vehicle and Phase

Table C-1

Linear Regression Equations for
Unburned Hydrocarbons (ppm) versus
Temperature and Humidity

Vehicle Number	Linear Regression Equation	S_e	r	r^2
PHASE I				
1	HC (ppm) = 493.8 + 1.9029 ΔT + 0.0791 ΔH	51.24	0.474	0.226
2	HC (ppm) = 497.4 - 2.1520 ΔT + 0.4558 ΔH	85.80	0.287	0.083
3	HC (ppm) = 320.5 + 0.1932 ΔH + 0.2588 ΔT	33.41	0.319	0.102
4	HC (ppm) = 353.4 + 0.4291 ΔH - 0.4122 ΔT	44.62	0.367	0.136
5	HC (ppm) = 472.7 - 3.1192 ΔT + 0.3538 ΔH	67.46	0.473	0.225
6	HC (ppm) = 285.2 + 0.3244 ΔH - 0.4128 ΔT	29.38	0.396	0.158
7	HC (ppm) = 949.2 - 0.8945 ΔT + 0.8315 ΔH	111.51	0.296	0.088
8	HC (ppm) = 868.6 - 7.3787 ΔT + 1.9108 ΔH	182.06	0.457	0.210
PHASE II				
1	HC (ppm) = 396.7 + 0.1985 ΔH + 0.1653 ΔT	31.64	0.324	0.106
2	HC (ppm) = 353.2 + 0.3104 ΔH - 0.8237 ΔT	28.76	0.413	0.172
3	HC (ppm) = 331.6 - 1.1433 ΔT + 0.2304 ΔH	20.17	0.556	0.311
4	HC (ppm) = 339.4 - 2.1562 ΔT + 0.3878 ΔH	33.60	0.610	0.375
5	HC (ppm) = 348.8 - 1.4681 ΔT + 0.2861 ΔH	14.26	0.770	0.597
6	HC (ppm) = 276.0 + 0.4418 ΔH + 0.1035 ΔT	29.19	0.593	0.354
7	HC (ppm) = 432.2 - 1.8885 ΔT + 0.0571 ΔH	47.63	0.455	0.208
8	HC (ppm) = 662.5 + 1.0798 ΔH - 2.3483 ΔT	50.24	0.659	0.436

NOTE: T = Observed temperature (^{o}F) minus average temperature (80.6^{o}F)

H = Observed humidity (grains/lb.) minus average humidity (74 grains/lb.)

S_e = Standard error or the estimate

r = Multiple correlation coefficient of HC with T and H.

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Table C-2

Linear Regression Equations for
Percent Carbon Monoxide versus
Temperature and Humidity

Vehicle Number	Linear Regression Equation	S_e	r	r^2
PHASE I				
1	CO (%) = 0.99 - 0.0063 ΔT + 0.0004 ΔH	0.091	0.727	0.529
2	CO (%) = 1.04 - 0.0043 ΔT + 0.0008 ΔH	0.142	0.338	0.114
3	CO (%) = 0.83 - 0.0114 ΔT + 0.0005 ΔH	0.191	0.597	0.356
4	CO (%) = 1.38 - 0.0163 ΔT + 0.0012 ΔH	0.169	0.754	0.569
5	CO (%) = 1.63 + 0.0022 ΔH - 0.0064 ΔT	0.132	0.595	0.354
6	CO (%) = 2.29 + 0.0201 ΔT + 0.0022 ΔH	0.299	0.752	0.566
7	CO (%) = 2.61 + 0.0117 ΔT + 0.0018 ΔH	0.252	0.645	0.416
8	CO (%) = 3.74 + 0.0215 ΔT + 0.0044 ΔH	1.441	0.287	0.082
PHASE II				
1	CO (%) = 1.13 - 0.0066 ΔT + 0.0015 ΔH	0.125	0.588	0.346
2	CO (%) = 1.32 - 0.0099 ΔT + 0.0014 ΔH	0.089	0.788	0.621
3	CO (%) = 0.91 - 0.0170 ΔT + 0.0015 ΔH	0.120	0.858	0.736
4	CO (%) = 1.33 - 0.0201 ΔT + 0.0023 ΔH	0.147	0.853	0.728
5	CO (%) = 0.81 - 0.0072 ΔT + 0.0017 ΔH	0.104	0.650	0.423
6	CO (%) = 2.56 + 0.0179 ΔT + 0.0018 ΔH	0.371	0.621	0.386
7	CO (%) = 2.86 + 0.0087 ΔT + 0.0021 ΔH	0.252	0.603	0.364
8	CO (%) = 5.23 + 0.0033 ΔH + 0.0114 ΔT	0.270	0.705	0.497

NOTE: T = Observed temperature (^{o}F) minus average temperature (80.6^{o}F)

H = Observed humidity (grains/lb.) minus average humidity (74 grains/lb.)

S_e = Standard error or the estimate

r = Multiple correlation coefficient of CO with T and H.

Table C-3

Linear Regression Equations for
Nitric Oxide (ppm) versus
Temperature and Humidity

Vehicle Number	Linear Regression Equation	S_e	r	r^2
	PHASE I			
1	NO (ppm) = 1628 - 6.2382 ΔH + 1.0702 ΔT	142.5	0.895	0.801
2	NO (ppm) = 1763 - 6.0755 ΔH - 3.6357 ΔT	149.0	0.903	0.815
3	NO (ppm) = 1496 - 5.5868 ΔH + 3.4984 ΔT	184.5	0.795	0.632
4	NO (ppm) = 1150 - 5.8453 ΔH + 2.6718 ΔT	79.8	0.955	0.912
5	NO (ppm) = 1961 - 7.5650 ΔH - 3.4675 ΔT	205.6	0.880	0.774
6	NO (ppm) = 1047 - 5.1638 ΔH - 2.9384 ΔT	156.1	0.856	0.733
7	NO (ppm) = 1522 - 5.4825 ΔH + 1.3973 ΔT	194.4	0.788	0.621
8	NO (ppm) = 449 - 6.5324 ΔT - 0.8779 ΔH	202.1	0.492	0.242
	PHASE II			
1	NO (ppm) = 1267 - 4.8415 ΔH + 0.2700 ΔT	90.1	0.926	0.857
2	NO (ppm) = 1365 - 5.3353 ΔH + 1.8480 ΔT	79.3	0.949	0.901
3	NO (ppm) = 1546 - 5.8875 ΔH + 5.8465 ΔT	97.3	0.930	0.865
4	NO (ppm) = 1286 - 5.3734 ΔH + 3.6958 ΔT	104.0	0.911	0.830
5	NO (ppm) = 1953 - 8.2308 ΔH + 8.6710 ΔT	121.8	0.942	0.877
6	NO (ppm) = 1145 - 4.6519 ΔH - 1.5256 ΔT	154.1	0.830	0.689
7	NO (ppm) = 805 - 2.8445 ΔH - 0.9948 ΔT	82.6	0.863	0.745
8	NO (ppm) = 278 - 2.1803 ΔT - 0.5195 ΔH	47.8	0.699	0.489

NOTE: T = Observed temperature (^{o}F) minus average temperature (80.6^{o}F)

H = Observed humidity (grains/lb.) minus average humidity (74 grains/lb.)

S_e = Standard error or the estimate

r = Multiple correlation coefficient of NO with T and H.

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Table C-4

Linear Regression Equations for
Unburned Hydrocarbons (grams/mile) versus
Temperature and Humidity

Vehicle Number	Linear Regression Equation	S_e	r	r^2
	PHASE I			
1	HC (gms/mile) = 5.76 + 0.0150 ΔT - 0.0036 ΔH	0.633	0.282	0.079
2	HC (gms/mile) = 5.82 - 0.0240 ΔT + 0.0020 ΔH	1.147	0.241	0.058
3	HC (gms/mile) = 4.65 + 0.0053 ΔH + 0.0048 ΔT	0.570	0.333	0.110
4	HC (gms/mile) = 5.71 - 0.0430 ΔT + 0.0100 ΔH	0.794	0.552	0.304
5	HC (gms/mile) = 7.93 - 0.0966 ΔT - 0.0088 ΔH	4.031	0.359	0.128
6	HC (gms/mile) = 3.23 - 0.0043 ΔT + 0.0008 ΔH	0.388	0.132	0.017
7	HC (gms/mile) = 6.55 - 0.0204 ΔT + 0.0003 ΔH	0.924	0.277	0.076
8	HC (gms/mile) = 8.08 + 0.0109 ΔH - 0.0224 ΔT	0.984	0.412	0.169
	PHASE II			
1	HC (gms/mile) = 5.13 - 0.0028 ΔT + 0.0000 ΔH	0.587	0.067	0.004
2	HC (gms/mile) = 4.82 - 0.0037 ΔT - 0.0005 ΔH	0.344	0.194	0.037
3	HC (gms/mile) = 5.06 - 0.0398 ΔT + 0.0042 ΔH	0.384	0.770	0.592
4	HC (gms/mile) = 5.80 - 0.0684 ΔT + 0.0024 ΔH	0.781	0.747	0.558
5	HC (gms/mile) = 4.40 - 0.0224 ΔT + 0.0017 ΔH	0.301	0.666	0.443
6	HC (gms/mile) = 3.59 + 0.0110 ΔT + 0.0000 ΔH	0.425	0.317	0.100
7	HC (gms/mile) = 5.30 - 0.0610 ΔT - 0.0018 ΔH	1.169	0.594	0.352
8	HC (gms/mile) = 7.92 - 0.0584 ΔT + 0.0119 ΔH	0.820	0.645	0.416

NOTE: T = Observed temperature (^{o}F) minus average temperature (80.6^{o}F)

H = Observed humidity (grains/lb.) minus average humidity (74 grains/lb.)

S_e = Standard error or the estimate

r = Multiple correlation coefficient of HC with T and H.

Table C-5

Linear Regression Equations for
Carbon Monoxide (grams/mile) versus
Temperature and Humidity

Vehicle Number	Linear Regression Equation	S_e	r	r^2
	PHASE I			
1	CO (gms/mile) = 33.74 - 0.2249 ΔT + 0.0100 ΔH	4.987	0.489	0.239
2	CO (gms/mile) = 30.79 + 0.0407 ΔH - 0.0821 ΔT	6.280	0.254	0.064
3	CO (gms/mile) = 31.13 - 0.5107 ΔT + 0.0254 ΔH	6.722	0.684	0.467
4	CO (gms/mile) = 52.26 - 0.9750 ΔT + 0.0507 ΔH	8.739	0.808	0.652
5	CO (gms/mile) = 64.70 - 0.8332 ΔT - 0.0486 ΔH	26.528	0.426	0.181
6	CO (gms/mile) = 65.22 + 0.3607 ΔT + 0.0819 ΔH	9.231	0.637	0.405
7	CO (gms/mile) = 36.27 + 0.0596 ΔH + 0.1281 ΔT	8.432	0.425	0.180
8	CO (gms/mile) = 70.55 + 0.4575 ΔT + 0.0978 ΔH	22.797	0.379	0.143
	PHASE II			
1	CO (gms/mile) = 38.78 - 0.1359 ΔT - 0.0106 ΔH	8.807	0.240	0.057
2	CO (gms/mile) = 40.12 - 0.4122 ΔT + 0.0317 ΔH	4.546	0.735	0.540
3	CO (gms/mile) = 32.02 - 0.8025 ΔT + 0.0236 ΔH	6.014	0.862	0.743
4	CO (gms/mile) = 50.13 - 1.2300 ΔT + 0.0808 ΔH	8.790	0.866	0.749
5	CO (gms/mile) = 30.17 - 0.4322 ΔT + 0.0354 ΔH	6.035	0.648	0.419
6	CO (gms/mile) = 65.53 + 0.2941 ΔT - 0.0071 ΔH	7.871	0.432	0.186
7	CO (gms/mile) = 36.83 - 0.0418 ΔH + 0.1361 ΔT	5.104	0.345	0.119
8	CO (gms/mile) = 87.21 + 0.0546 ΔH - 0.0654 ΔT	7.384	0.292	0.085

NOTE: T = Observed temperature (^{o}F) minus average temperature (80.6^{o}F)

H = Observed humidity (grains/lb.) minus average humidity (74 grains/lb.)

S_e = Standard error or the estimate

r = Multiple correlation coefficient of CO with T and H.

Table C-6

Linear Regression Equations for
Oxides of Nitrogen (grams/mile) versus
Temperature and Humidity

Vehicle Number	Linear Regression Equation	S_e	r	r^2
	PHASE I			
1	NO_x(gms/mile) = 8.63 - 0.0527 ΔH + 0.0630 ΔT	1.453	0.831	0.690
2	NO_x(gms/mile) = 7.72 - 0.0292 ΔH + 0.0133 ΔT	1.258	0.716	0.512
3	NO_x(gms/mile) = 8.43 - 0.0288 ΔH + 0.0551 ΔT	1.015	0.754	0.568
4	NO_x(gms/mile) = 6.19 - 0.0262 ΔH + 0.0558 ΔT	0.452	0.921	0.848
5	NO_x(gms/mile) = 8.75 - 0.0409 ΔH + 0.0336 ΔT	1.051	0.856	0.732
6	NO_x(gms/mile) = 3.09 - 0.0057 ΔH - 0.0186 ΔT	0.665	0.564	0.318
7	NO_x(gms/mile) = 6.81 - 0.0098 ΔH + 0.0101 ΔT	0.938	0.400	0.160
8	NO_x(gms/mile) = 1.90 - 0.0282 ΔT - 0.0026 ΔH	0.943	0.434	0.188
	PHASE II			
1	NO_x(gms/mile) = 5.81 - 0.0259 ΔH + 0.0071 ΔT	0.810	0.826	0.682
2	NO_x(gms/mile) = 5.77 - 0.0262 ΔH + 0.0157 ΔT	0.577	0.892	0.795
3	NO_x(gms/mile) = 7.71 - 0.0341 ΔH + 0.0564 ΔT	0.889	0.841	0.707
4	NO_x(gms/mile) = 6.36 - 0.0351 ΔH + 0.0506 ΔT	0.767	0.881	0.776
5	NO_x(gms/mile) = 7.61 - 0.0392 ΔH + 0.0419 ΔT	0.622	0.934	0.872
6	NO_x(gms/mile) = 2.69 - 0.0118 ΔH + 0.0019 ΔT	0.444	0.775	0.600
7	NO_x(gms/mile) = 3.46 - 0.0062 ΔH - 0.0032 ΔT	0.445	0.578	0.334
8	NO_x(gms/mile) = 1.06 - 0.0020 ΔH + 0.0056 ΔT	0.411	0.204	0.041

NOTE: T = Observed temperature (^oF) minus average temperature (80.6^oF)

H = Observed humidity (grains/lb.) minus average humidity (74 grains/lb.)

S_e = Standard error or the estimate

r = Multiple correlation coefficient of NO_x with T and H.

APPENDIX D

General Quadratic Regression

Equations by Vehicle

and Phase

Table D-1

Quadratic Regression Equation for
Unburned Hydrocarbon (ppm) versus
Temperature and Humidity

Veh. No.	Quadratic Regression Equation	S_e	r	r^2
	PHASE I			
1	HC (ppm) = + 476.6 + 2.4591 ΔT + 0.0155 ΔTH - 0.1821 ΔH + 0.0041 ΔH^2 + 0.0328 ΔT^2	53.133	0.559	0.312
2	HC (ppm) = + 544.1 - 0.3249 ΔT^2 - 3.0647 ΔT + 0.3753 ΔH + 0.0466 ΔTH - 0.0052 ΔH^2	82.073	0.555	0.308
3	HC (ppm) = + 332.0 - 0.1253 ΔT^2 + 0.0497 ΔTH + 0.5276 ΔT - 0.0031 ΔH^2 - 0.0149 ΔH	32.081	0.564	0.318
4	HC (ppm) = + 346.6 + 0.2815 ΔH + 0.0077 ΔTH + 0.0026 ΔH^2 - 0.2246 ΔT - 0.0015 ΔT^2	49.423	0.406	0.165
5	HC (ppm) = + 496.8 - 3.7101 ΔT - 0.1142 ΔT^2 + 0.4890 ΔH - 0.0042 ΔH^2 + 0.0047 ΔT^2	71.087	0.538	0.289
6	HC (ppm) = + 277.0 + 0.3364 ΔH + 0.0483 ΔT^2 - 0.6003 ΔT + 0.0048 ΔH^2 - 0.0287 ΔTH	31.388	0.467	0.218
7	HC (ppm) = + 930.3 + 0.0093 ΔH^2 + 0.5587 ΔH - 0.8019 ΔT + 0.0251 ΔT^2 - 0.0093 ΔTH	121.040	0.338	0.114
8	HC (ppm) = + 951.7 - 6.6560 ΔT + 2.7554 ΔH - 0.0465 ΔH^2 + 0.1231 ΔTH - 0.1908 ΔT^2	180.803	0.598	0.358
	PHASE II			
1	HC (ppm) = + 386.7 + 0.4496 ΔH + 0.0950 ΔT^2 - 0.0375 ΔTH + 0.0015 ΔH^2 - 0.2026 ΔT	32.947	0.517	0.267
2	HC (ppm) = + 352.3 + 0.4589 ΔH - 1.4021 ΔT - 0.0411 ΔTH + 0.0035 ΔH^2 + 0.0356 ΔT^2	29.376	0.536	0.287
3	HC (ppm) = + 328.4 - 1.2372 ΔT + 0.3057 ΔH + 0.0394 ΔH^2 - 0.0159 ΔTH + 0.0007 ΔH^2	21.426	0.599	0.359
4	HC (ppm) = + 330.5 - 2.4455 ΔT + 0.4227 ΔH + 0.0049 ΔH^2 - 0.0293 ΔTH + 0.0473 ΔT^2	36.093	0.641	0.411
5	HC (ppm) = + 345.1 - 1.5883 ΔT + 0.2991 ΔH + 0.0021 ΔH^2 - 0.0135 ΔTH + 0.0217 ΔT^2	15.204	0.787	0.619
6	HC (ppm) = + 287.3 + 0.6236 ΔH - 0.0065 ΔH^2 + 0.0074 ΔTH + 0.1148 ΔT - 0.0072 ΔT^2	28.921	0.690	0.476
7	HC (ppm) = + 417.3 + 0.1226 ΔT^2 - 1.0559 ΔT - 0.0036 ΔH^2 + 0.0929 ΔH + 0.0109 ΔTH	46.521	0.600	0.360
8	HC (ppm) = + 623.8 + 0.0093 ΔTH + 0.8102 ΔH + 0.1754 ΔT^2 - 1.1296 ΔT + 0.0050 ΔH^2	40.986	0.830	0.689

Table D-2

Quadratic Regression Equation for
Carbon Monoxide (%) Versus
Temperature and Humidity

Veh. No.	Quadratic Regression Equation	S_e	r	r^2
	PHASE I			
1.	CO (%) = + 1.001 - 0.0075 ΔT + 0.0001 ΔTH + 0.0001 ΔT^2 + 0.0004 ΔH + 0.0000 ΔH^2	0.086	0.807	0.651
2.	CO (%) = + 1.122 - 0.0047 ΔT + 0.0004 ΔT^2 + 0.0009 ΔH + 0.0000 ΔH^2 + 0.0001 ΔTH	0.142	0.515	0.265
3.	CO (%) = + 0.891 - 0.0095 ΔT + 0.0003 ΔTH - 0.0007 ΔT^2 - 0.0009 ΔH - 0.0000 ΔH^2	0.176	0.741	0.549
4.	CO (%) = + 1.428 - 0.0185 ΔT - 0.0005 ΔT^2 + 0.0000 ΔH^2 + 0.0004 ΔH + 0.0000 ΔTH	0.159	0.829	0.687
5.	CO (%) = + 1.665 + 0.0022 ΔH - 0.0079 ΔT - 0.0002 ΔT^2 + 0.0000 ΔH^2 + 0.0000 ΔTH	0.139	0.635	0.403
6.	CO (%) = + 2.316 + 0.0152 ΔT + 0.0000 ΔH^2 - 0.0004 ΔT^2 + 0.0015 ΔH - 0.0001 ΔTH	0.305	0.796	0.634
7.*				
8.	CO (%) = + 2.985 + 0.0002 ΔH^2 + 0.0280 ΔT + 0.0024 ΔT^2 - 0.0005 ΔTH - 0.0022 ΔH	1.437	0.498	0.248
	PHASE II			
1.	CO (%) = + 1.116 + 0.0000 ΔTH - 0.0057 ΔT + 0.0000 ΔH^2 + 0.0005 ΔH - 0.0000 ΔT^2	0.120	0.620	0.384
2.	CO (%) = + 1.329 - 0.0107 ΔT + 0.0009 ΔH + 0.0000 ΔH^2 - 0.0007 ΔT^2 + 0.0000 ΔTH	0.085	0.848	0.719
3.	CO (%) = + 0.890 - 0.0132 ΔT + 0.0002 ΔTH + 0.0003 ΔH - 0.0000 ΔH^2 - 0.0000 ΔT^2	0.104	0.915	0.837
4.	CO (%) = + 1.309 - 0.0201 ΔT + 0.0000 ΔH^2 + 0.0008 ΔH - 0.0002 ΔT^2 + 0.0000 ΔTH	0.135	0.901	0.812
5.	CO (%) = + 0.779 - 0.0000 ΔTH - 0.0066 ΔT + 0.0014 ΔH + 0.0001 ΔT^2 + 0.0000 ΔH^2	0.110	0.680	0.462
6.	CO (%) = + 2.607 + 0.0221 ΔT + 0.0017 ΔH - 0.0000 ΔH^2 + 0.0002 ΔTH - 0.0001 ΔT^2	0.399	0.644	0.415
7.	CO (%) = + 2.842 + 0.0105 ΔT + 0.0029 ΔH + 0.0004 ΔT^2 - 0.0000 ΔH^2 - 0.0000 ΔTH	0.265	0.648	0.420
8.	CO (%) = + 5.273 + 0.0031 ΔH - 0.0004 ΔT^3 + 0.0061 ΔT + 0.0000 ΔH^2 - 0.0001 ΔTH	0.272	0.762	0.581

* Indicates unreliable computer output.

Table D-3

Quadratic Regression Equation for
Nitric Oxide (ppm) versus
Temperature and Humidity

Veh. No.	Quadratic Regression Equation	S_e	r	r^2
	PHASE I			
1	NO (ppm) = + 1592.0 - 7.1277 ΔH + 0.0248 ΔH^2 - 0.0775 ΔT^2 + 1.0772 ΔT + 0.0024 Δ TH	144.282	0.912	0.832
2	NO (ppm) = + 1632.4 - 6.6498 ΔH + 0.0746 ΔH^2 - 0.1111 ΔT - 0.3158 Δ TH + 0.5012 ΔT^2	102.344	0.963	0.927
3	NO (ppm) = + 1402.7 - 5.8980 ΔH + 0.0778 ΔH^2 - 0.3662 Δ TH + 0.3080 ΔT^2 - 0.9928 Δ T	157.743	0.882	0.778
4	NO (ppm) = + 1109.0 - 6.1516 ΔH + 2.8760 ΔT + 0.0158 ΔH^2 + 0.1438 ΔT^2 + 0.0408 Δ TH	80.511	0.962	0.925
5	NO (ppm) = + 2039.7 - 8.1740 ΔH - 0.6547 ΔT^2 - 3.6044 ΔT + 0.1820 Δ TH - 0.0150 ΔH^2	208.921	0.899	0.808
6	NO (ppm) = + 1070.0 - 6.6434 ΔH + 0.2954 Δ TH - 0.4679 ΔT^2 - 0.0176 ΔH^2 - 0.3805 Δ T	147.334	0.898	0.806
7	NO (ppm) = + 1547.3 - 6.3879 ΔH - 0.4594 ΔT^2 + 0.0121 ΔH^2 + 0.0793 Δ TH + 0.6760 Δ T	199.525	0.819	0.671
8	NO (ppm) = + 522.9 - 7.5566 ΔT - 0.0206 ΔH^2 - 0.3177 ΔT^2 - 0.4414 Δ H - 0.0508 Δ TH	213.800	0.549	0.301
	PHASE II			
1	NO (ppm) = + 1212.7 - 5.1677 ΔH + 0.0441 ΔH^2 - 0.2105 Δ TH + 0.2798 ΔT^2 - 1.4034 Δ T	72.002	0.964	0.929
2	NO (ppm) = + 1338.9 - 5.1985 ΔH - 0.1845 Δ TH + 0.0311 ΔT^2 + 0.1163 ΔT^2 - 0.7504 Δ T	66.578	0.970	0.941
3	NO (ppm) = + 1562.1 - 5.9607 ΔH + 6.5472 ΔT - 0.0106 ΔH^2 + 0.0684 Δ TH - 0.0936 ΔT^2	105.413	0.932	0.869
4	NO (ppm) = + 1296.0 - 4.8007 ΔH + 3.2518 ΔT - 0.0077 ΔH^2 + 0.0985 ΔT^2 - 0.0438 Δ TH	110.718	0.918	0.843
5	NO (ppm) = + 1987.1 - 7.1900 ΔH + 7.2798 ΔT - 0.0132 ΔH^2 - 0.0850 Δ TH + 0.0955 ΔT^2	118.350	0.955	0.912
6	NO (ppm) = + 1108.6 - 4.3906 ΔH + 0.2583 ΔT^2 - 0.1445 Δ TH + 0.0193 ΔT^2 - 2.7274 Δ T	164.620	0.842	0.709
7	NO (ppm) = + 777.2 - 3.0139 ΔH + 0.0230 ΔH^2 - 0.0966 Δ TH - 2.1967 ΔT + 0.0710 ΔT^2	82.650	0.888	0.789
8	NO (ppm) = + 248.2 - 2.3376 Δ T - 0.6300 Δ H + 0.0128 Δ H2 + 0.1336 ΔT^2 - 0.0538 Δ TH	45.920	0.781	0.610

Table D-4

Quadratic Regression Equation for
Unburned Hydrocarbon (grams/mile) Versus
Temperature and Humidity

Veh. No.	Quadratic Regression Equation	S_e	r	r^2
	PHASE I			
1. *				
2.	HC (gms/mile) = + 6.496 - 0.0125 ΔT - 0.0047 ΔT^2 + 0.0020 ΔTH - 0.0002 ΔH^2 - 0.0016 ΔH	1.065	0.576	0.332
3.	HC (gms/mile) = + 4.693 + 0.0009 ΔTH - 0.0014 ΔT^2 - 0.0000 ΔH^2 + 0.0047 ΔT + 0.0001 ΔH	0.549	0.567	0.322
4.	HC (gms/mile) = + 5.461 - 0.0005 ΔTH - 0.0486 ΔT + 0.0081 ΔH + 0.0001 ΔH^2 + 0.0007 ΔT^2	0.829	0.613	0.376
5.	HC (gms/mile) = + 8.980 - 0.1218 ΔT - 0.0116 ΔT^2 + 0.0018 ΔTH - 0.0241 ΔH + 0.0001 ΔH^2	4.077	0.516	0.266
6.	HC (gms/mile) = + 3.189 + 0.0000 ΔH^2 - 0.0065 ΔT - 0.0001 ΔTH + 0.0005 ΔH + 0.0001 ΔT^2	0.408	0.217	0.047
7.	HC (gms/mile) = + 6.336 + 0.0007 ΔTH - 0.0053 ΔH - 0.0048 ΔT - 0.0000 ΔH^2 + 0.0000 ΔT^2	0.945	0.452	0.204
8.	HC (gms/mile) = + 7.689 + 0.0018 ΔH^2 + 0.0106 ΔH - 0.0353 ΔT - 0.0013 ΔTH + 0.0002 ΔT^2	0.994	0.550	0.303
	PHASE II			
1.	HC (gms/mile) = + 4.916 + 0.0020 ΔT^2 - 0.0003 ΔTH + 0.0027 ΔH - 0.0009 ΔT - 0.0000 ΔH^2	0.620	0.443	0.196
2.	HC (gms/mile) = + 4.819 - 0.0000 ΔH^2 + 0.0007 ΔT^2 + 0.0016 ΔH - 0.0007 ΔTH - 0.0025 ΔT	0.341	0.470	0.221
3.	HC (gms/mile) = + 4.959 - 0.0338 ΔT + 0.0007 ΔT^2 + 0.0001 ΔTH + 0.0040 ΔH - 0.0000 ΔH^2	0.397	0.801	0.642
4.	HC (gms/mile) = + 5.369 - 0.0666 ΔT + 0.0032 ΔT^2 + 0.0055 ΔH - 0.0009 ΔTH + 0.0000 ΔH^2	0.756	0.815	0.664
5.	HC (gms/mile) = + 4.328 - 0.0162 ΔT + 0.0004 ΔT^2 + 0.0002 ΔTH + 0.0010 ΔH - 0.0000 ΔH^2	0.304	0.728	0.530
6.	HC (gms/mile) = + 3.742 + 0.0176 ΔT - 0.0001 ΔH^2 + 0.0011 ΔH + 0.0004 ΔTH - 0.0002 ΔT^2	0.448	0.511	0.261
7.	HC (gms/mile) = + 5.191 - 0.0378 ΔT + 0.0006 ΔT^2 - 0.0038 ΔH + 0.0010 ΔTH - 0.0001 ΔH^2	1.211	0.655	0.429
8.	HC (gms/mile) = + 7.605 - 0.0000 ΔTH - 0.0562 ΔT + 0.0001 ΔH^2 + 0.0003 ΔT^2 + 0.0070 ΔH	0.827	0.714	0.510

* Indicates unreliable computer output.

Scott Research Laboratories, Inc.
Project #2846

April 24, 1970

Table D-5

Quadratic Regression Equations for
Carbon Monoxide (grams/mile) Versus
Temperature and Humidity

Veh. No.	Quadratic Regression Equation	S_e	r	r^2
	PHASE I			
1.	CO (gms/mile) = + 33.095 - 0.2644 ΔT - 0.0001 ΔH^2 + 0.0185 ΔT^2 + 0.0598 ΔH - 0.0068 ΔTH	4.368	0.720	0.518
2.	CO (gms/mile) = + 33.414 + 0.0133 ΔTH - 0.0023 ΔH^2 + 0.0342 ΔH - 0.0123 ΔT^2 + 0.0832 ΔT	5.653	0.613	0.376
3.	CO (gms/mile) = + 32.624 - 0.4202 ΔT + 0.0006 ΔTH - 0.0217 ΔT^2 - 0.0006 ΔH^2 - 0.0239 ΔH	6.478	0.770	0.593
4.	CO (gms/mile) = + 51.469 - 0.9753 ΔT + 0.0423 ΔH + 0.0003 ΔH^2 + 0.0019 ΔT^2 - 0.0008 ΔTH	9.598	0.810	0.656
5.	CO (gms/mile) = + 69.731 - 0.9078 ΔT - 0.0734 ΔT^2 + 0.0154 ΔTH - 0.1800 ΔH + 0.0010 ΔH^2	26.846	0.556	0.309
6.	CO (gms/mile) = + 69.417 + 0.2865 ΔT + 0.0757 ΔH - 0.0268 ΔT^2 + 0.0040 ΔTH - 0.0004 ΔH^2	9.087	0.712	0.507
7.*				
8.	CO (gms/mile) = + 56.903 + 0.0059 ΔH^2 + 0.4761 ΔT + 0.0432 ΔT^2 - 0.0153 ΔTH - 0.0164 ΔH	21.843	0.594	0.353
	PHASE II			
1.	CO (gms/mile) = + 37.831 + 0.0107 ΔT^2 - 0.0005 ΔH^2 - 0.0736 ΔT + 0.0009 ΔTH + 0.0010 ΔH	9.532	0.321	0.103
2.	CO (gms/mile) = + 39.522 - 0.2898 ΔT + 0.0074 ΔTH - 0.0004 ΔH^2 - 0.0039 ΔT^2 - 0.0028 ΔH	4.330	0.810	0.656
3.	CO (gms/mile) = + 29.472 - 0.5451 ΔT + 0.0113 ΔTH - 0.0009 ΔH^2 + 0.0082 ΔT^2 - 0.0211 ΔH	4.367	0.942	0.887
4.	CO (gms/mile) = + 46.450 - 1.1378 ΔT - 0.0000 ΔTH + 0.0009 ΔH^2 + 0.0473 ΔH + 0.0122 ΔT^2	9.084	0.885	0.783
5.	CO (gms/mile) = + 28.485 - 0.3551 ΔT + 0.0025 ΔTH + 0.0041 ΔT^2 + 0.0106 ΔH + 0.0001 ΔH^2	6.343	0.687	0.472
6.	CO (gms/mile) = + 65.529 + 0.3382 ΔT - 0.0171 ΔT^2 + 0.0074 ΔTH - 0.0007 ΔH^2 - 0.0287 ΔH	8.327	0.500	0.250
7.	CO (gms/mile) = + 33.641 + 0.0196 ΔT^2 + 0.2025 ΔT - 0.0447 ΔH + 0.0004 ΔH^2 - 0.0023 ΔTH	4.760	0.607	0.368
8.*				

* Indicates unreliable computer output.

Table D-6

Quadratic Regression Equation for
Oxides of Nitrogen (grams/mile) Versus
Temperature and Humidity

Veh. No.	Quadratic Regression Equation	S_e	r	r^2
	PHASE I			
1.	NOx (gms/mile) = + 8.733 - 0.0666 ΔH + 0.0587 ΔT + 0.0002 ΔH^2 - 0.0051 ΔT^2 + 0.0010 ΔTH	1.228	0.904	0.817
2.	NOx (gms/mile) = + 7.820 - 0.0361 ΔH - 0.0029 ΔT^2 + 0.0001 ΔH^2 + 0.0003 ΔTH + 0.0054 ΔT	1.253	0.776	0.602
3.	NOx (gms/mile) = + 7.834 - 0.0228 ΔH + 0.0376 ΔT + 0.0048 ΔT^2 - 0.0024 ΔTH + 0.0002 ΔH^2	0.851	0.866	0.750
4.	NOx (gms/mile) = + 6.026 - 0.0256 ΔH + 0.0531 ΔT + 0.0011 ΔT^2 - 0.0004 ΔTH + 0.0000 ΔH^2	0.470	0.930	0.865
5.	NOx (gms/mile) = + 9.281 - 0.0459 ΔH - 0.0045 ΔT^2 + 0.0014 ΔTH + 0.0367 ΔT - 0.0001 ΔH^2	0.981	0.898	0.806
6.	NOx (gms/mile) = + 3.480 - 0.0158 ΔT - 0.0025 ΔT^2 - 0.0064 ΔH + 0.0009 ΔTH - 0.0001 ΔH^2	0.615	0.701	0.491
7.	NOx (gms/mile) = + 7.079 - 0.0095 ΔH - 0.0014 ΔT^2 + 0.0000 ΔH^2 + 0.0003 ΔTH + 0.0089 ΔT	1.010	0.446	0.199
8.	NOx (gms/mile) = + 2.616 - 0.0384 ΔT - 0.0034 ΔT^2 - 0.0001 ΔH^2 + 0.0005 ΔTH + 0.0006 ΔH	0.847	0.679	0.461
	PHASE II			
1.	NOx (gms/mile) = + 5.111 - 0.0305 ΔH + 0.0001 ΔH^2 + 0.0025 ΔT^2 + 0.0176 ΔT - 0.0002 ΔTH	0.646	0.914	0.835
2.	NOx (gms/mile) = + 5.434 - 0.0299 ΔH + 0.0000 ΔH^2 + 0.0257 ΔT + 0.0011 ΔT^2 + 0.0001 ΔTH	0.538	0.923	0.852
3.	NOx (gms/mile) = + 7.586 - 0.0340 ΔH + 0.0460 ΔT + 0.0001 ΔH^2 - 0.0007 ΔTH + 0.0004 ΔT^2	0.949	0.851	0.724
4.	NOx (gms/mile) = + 6.274 - 0.0331 ΔH + 0.0418 ΔT - 0.0006 ΔTH + 0.0000 ΔH^2 + 0.0008 ΔT^2	0.831	0.887	0.787
5.	NOx (gms/mile) = + 7.484 - 0.0373 ΔH + 0.0208 ΔT - 0.0014 ΔTH + 0.0002 ΔH^2 + 0.0007 ΔT^2	0.542	0.959	0.920
6.	NOx (gms/mile) = + 2.776 - 0.0093 ΔH - 0.0001 ΔH^2 + 0.0004 ΔT^2 + 0.0061 ΔT + 0.0001 ΔTH	0.435	0.828	0.686
7.	NOx (gms/mile) = + 3.162 - 0.0097 ΔH + 0.0002 ΔTH + 0.0072 ΔT + 0.0009 ΔT^2 + 0.0000 ΔH^2	0.380	0.774	0.599
8.	NOx (gms/mile) = + 1.125 - 0.0001 ΔH^2 + 0.0005 ΔTH + 0.0151 ΔT - 0.0015 ΔH + 0.0000 ΔT^2	0.398	0.510	0.260

APPENDIX E

Composite Vehicle Correction Factors

(Based on small sample - for

illustrative purposes only)

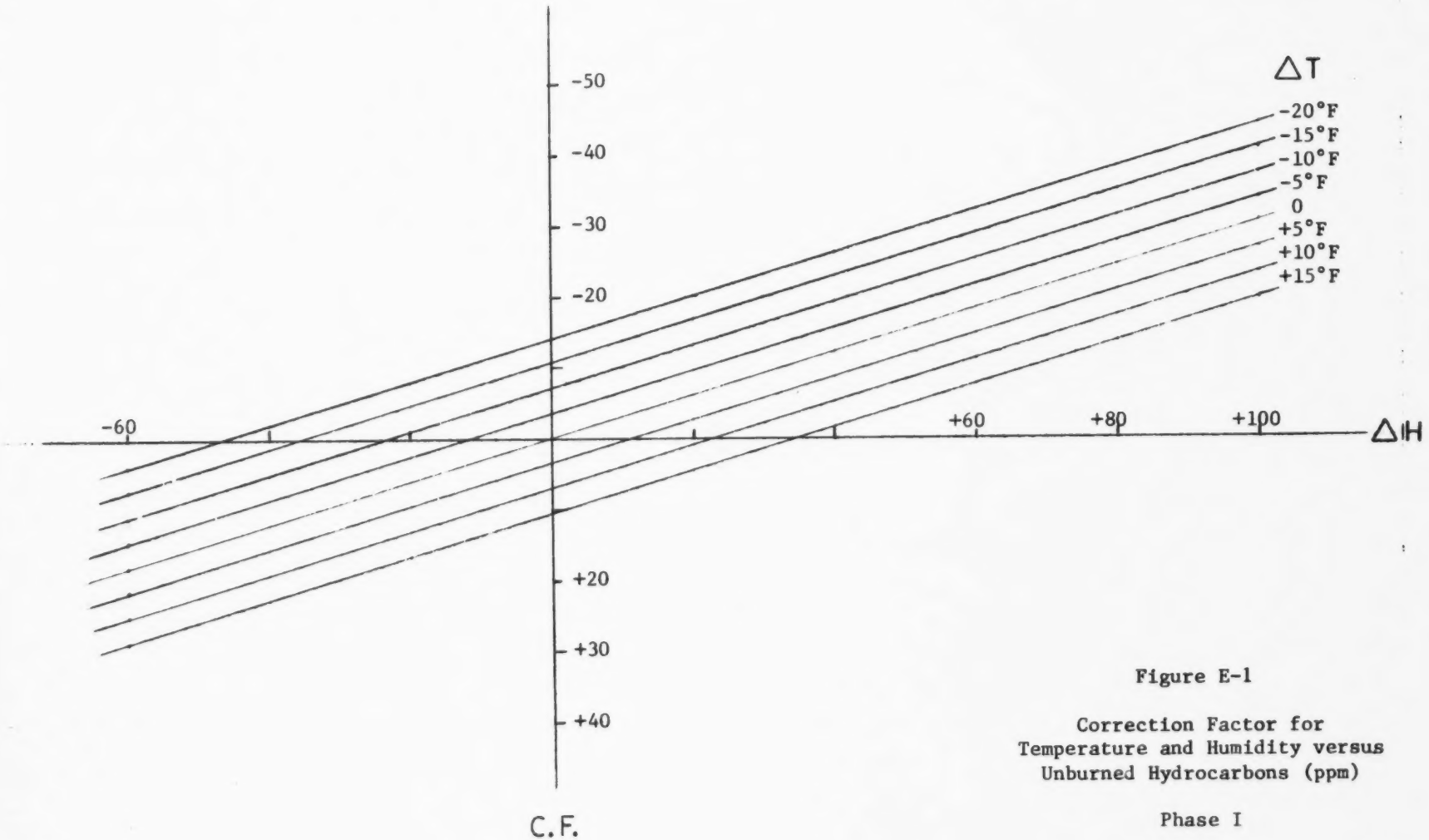

Figure E-1

Correction Factor for
Temperature and Humidity versus
Unburned Hydrocarbons (ppm)

Phase I

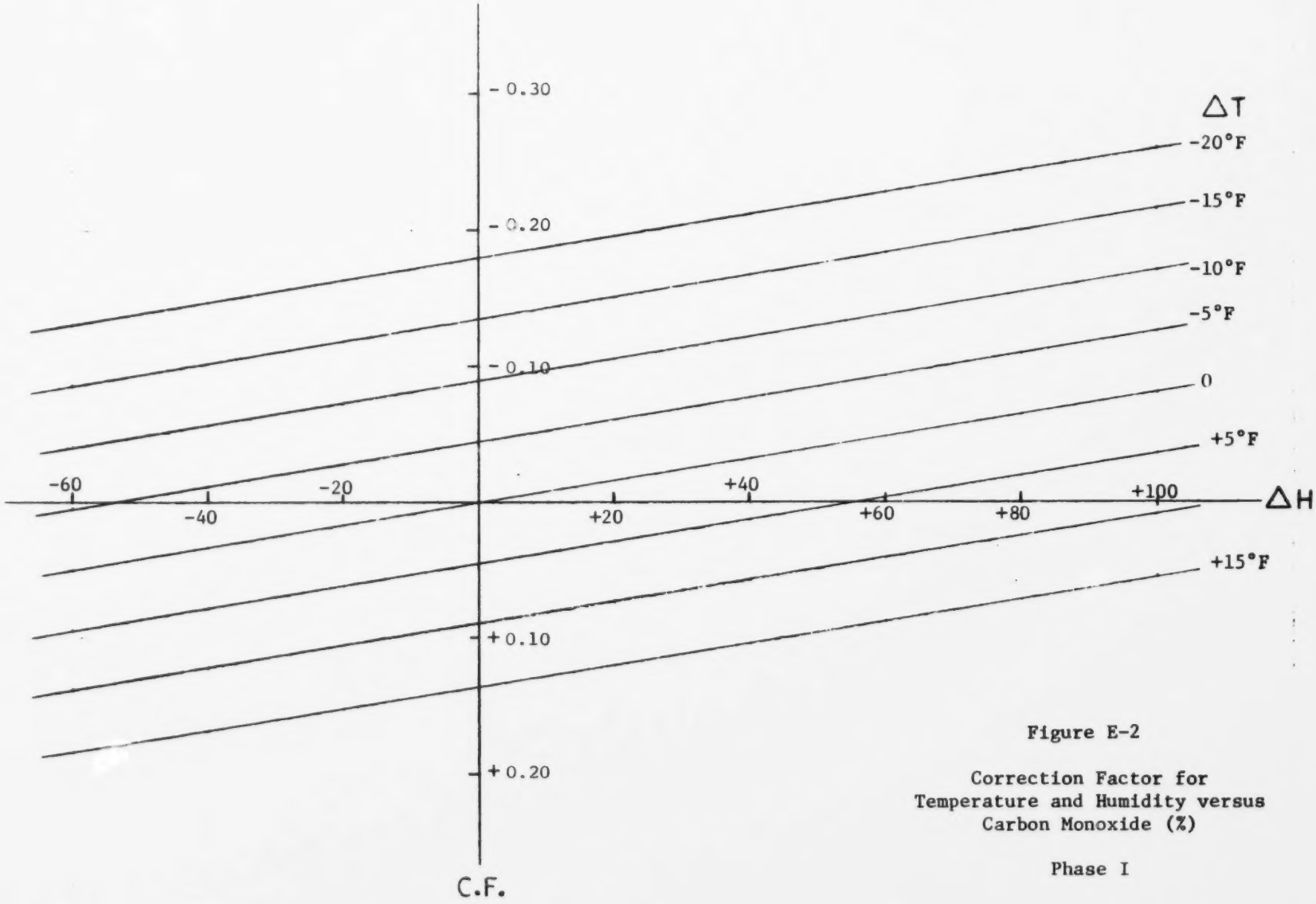

Figure E-2

Correction Factor for
Temperature and Humidity versus
Carbon Monoxide (%)

Phase I

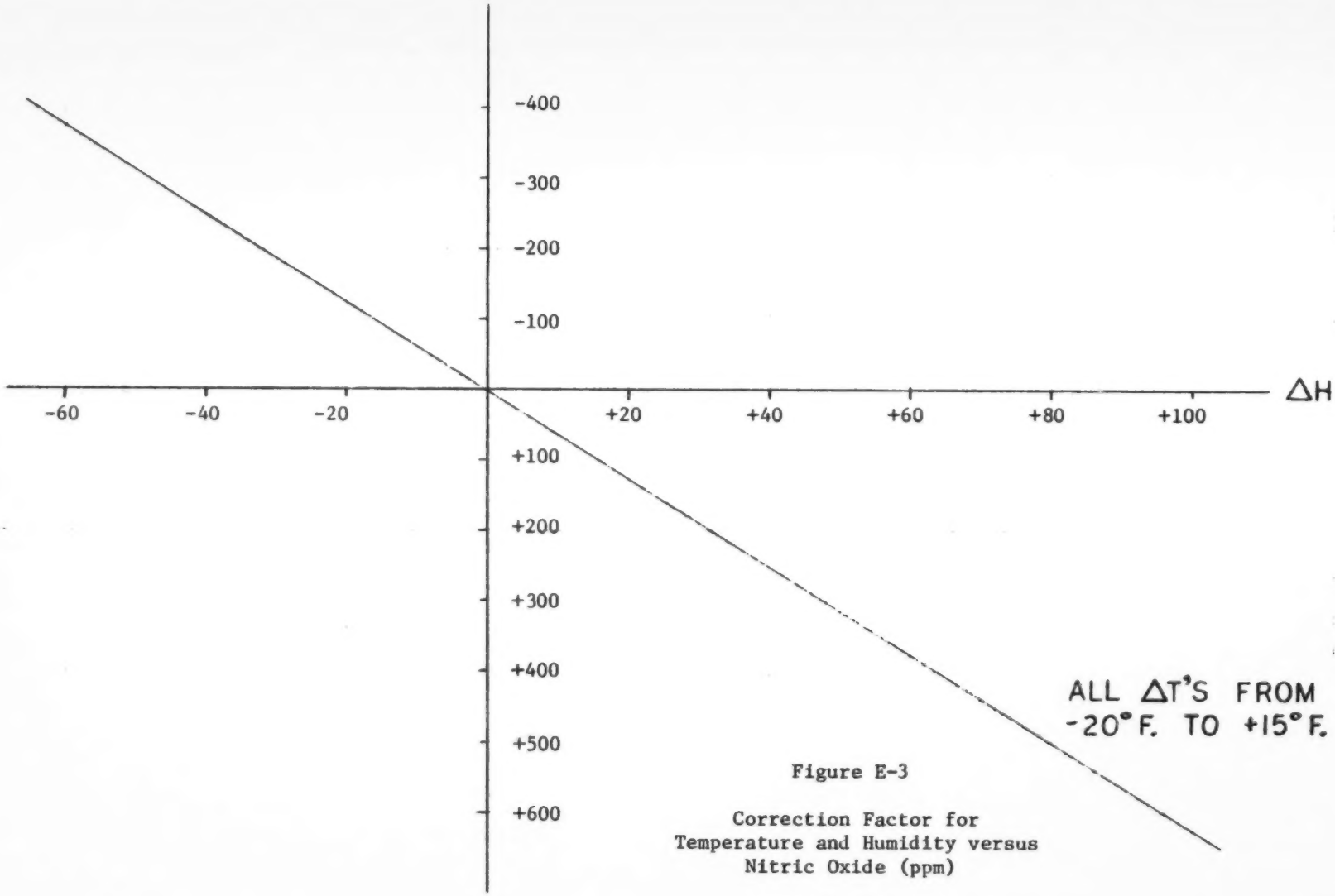

Figure E-3

Correction Factor for
Temperature and Humidity versus
Nitric Oxide (ppm)

Phase I

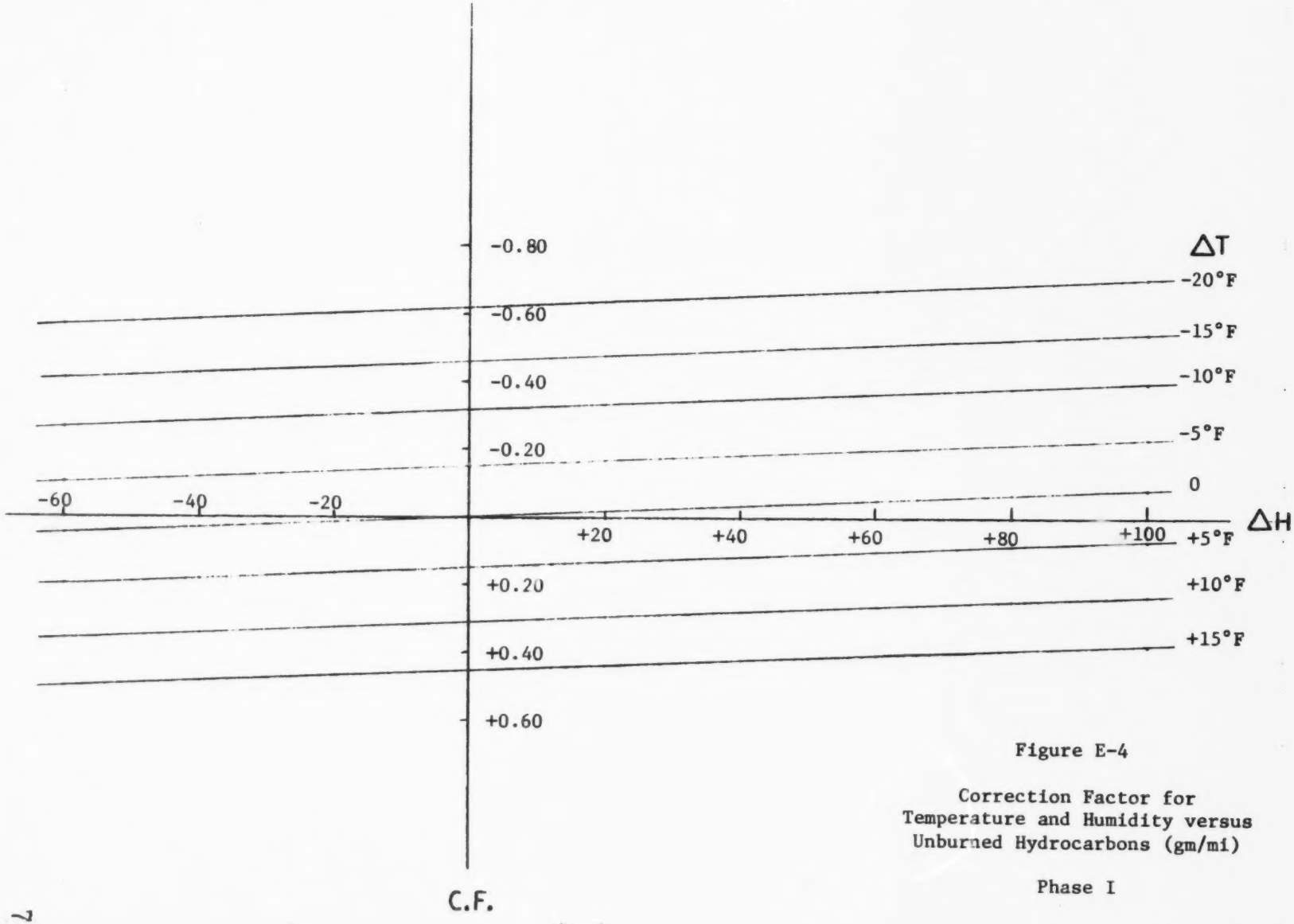

Figure E-4

Correction Factor for
Temperature and Humidity versus
Unburned Hydrocarbons (gm/mi)

Phase I

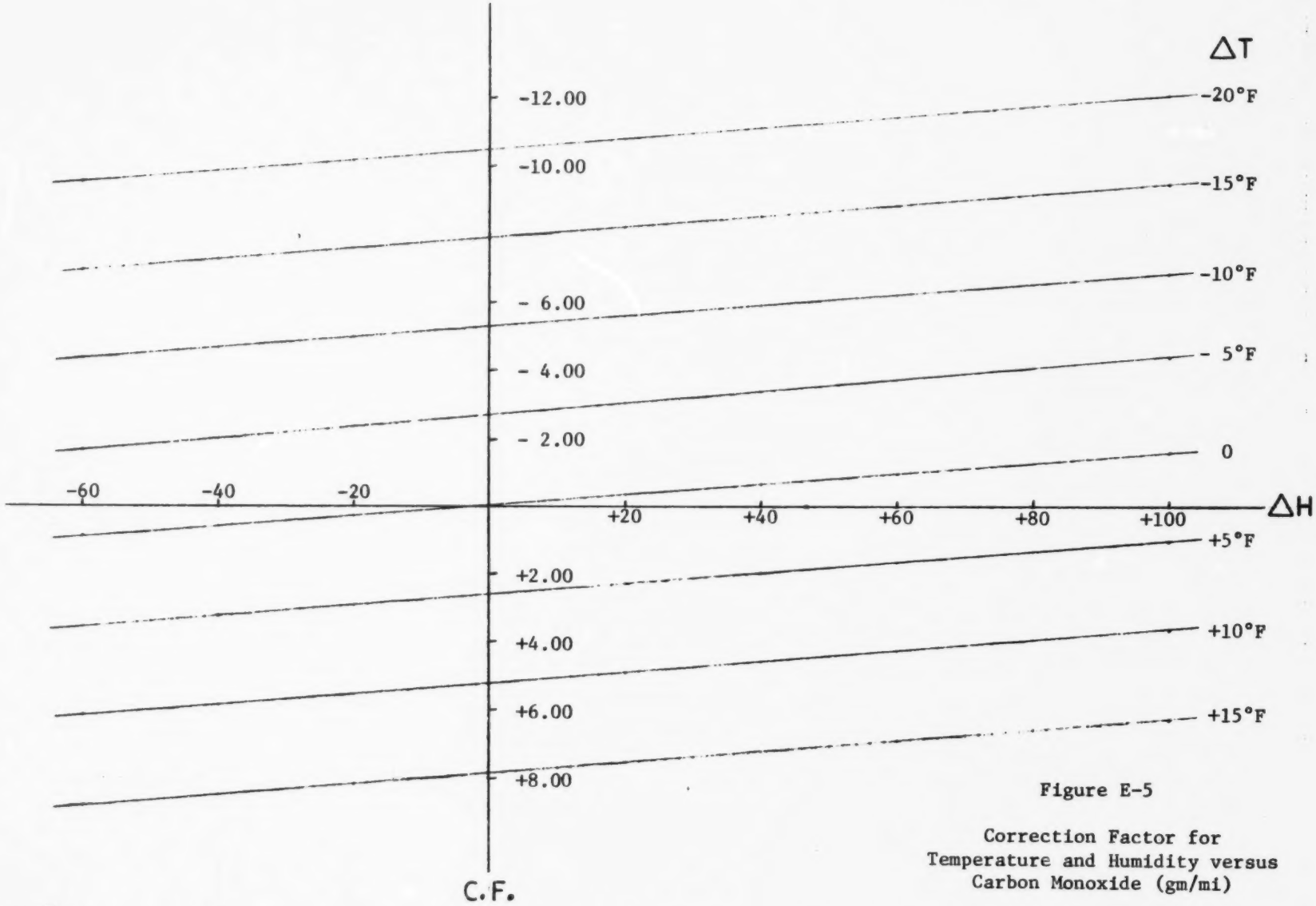

Figure E-5

Correction Factor for
Temperature and Humidity versus
Carbon Monoxide (gm/mi)

Phase I

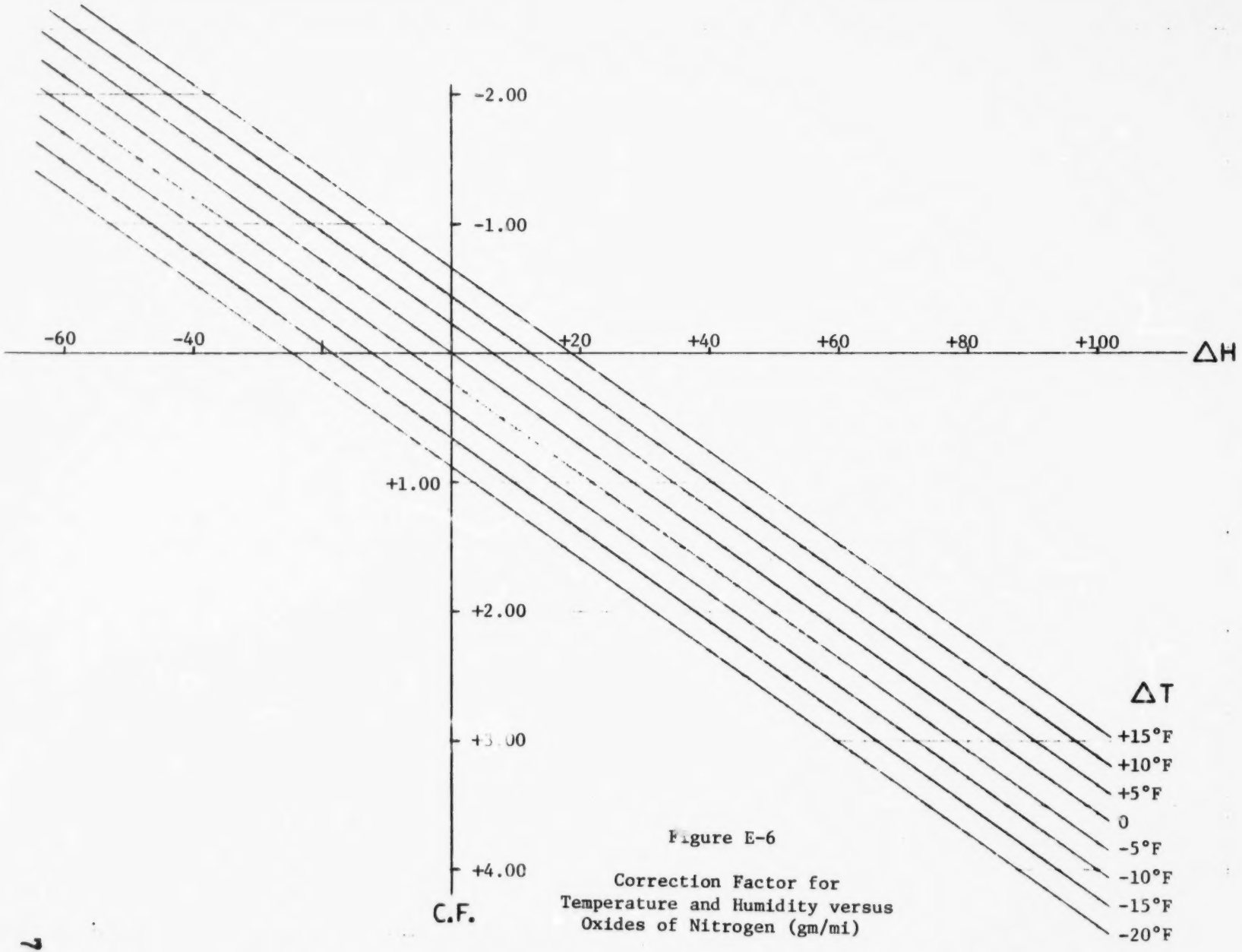

Figure E-6

Correction Factor for
Temperature and Humidity versus
Oxides of Nitrogen (gm/mi)

Phase I

Reproduced from best available copy.

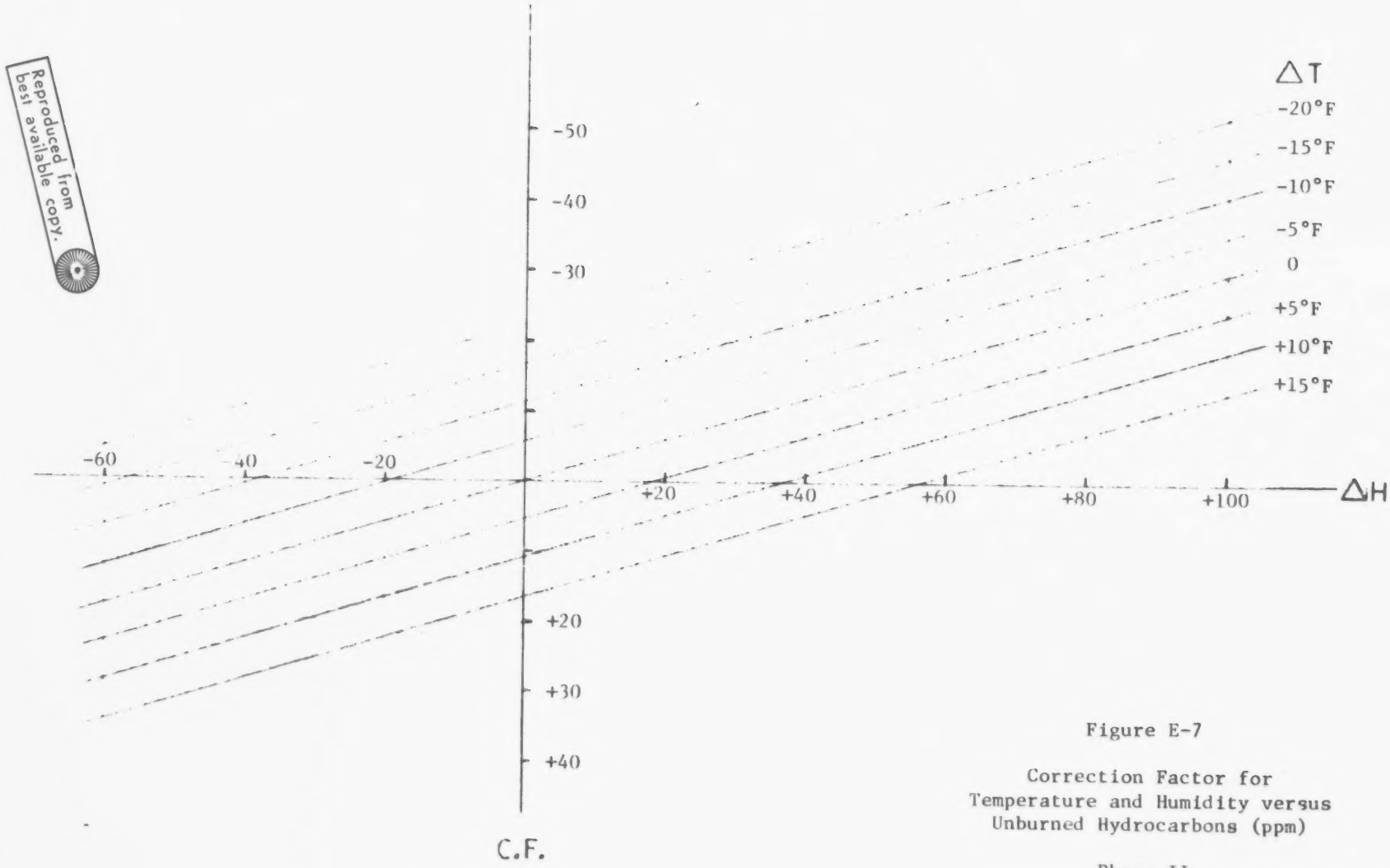

Figure E-7

Correction Factor for
Temperature and Humidity versus
Unburned Hydrocarbons (ppm)

Phase II

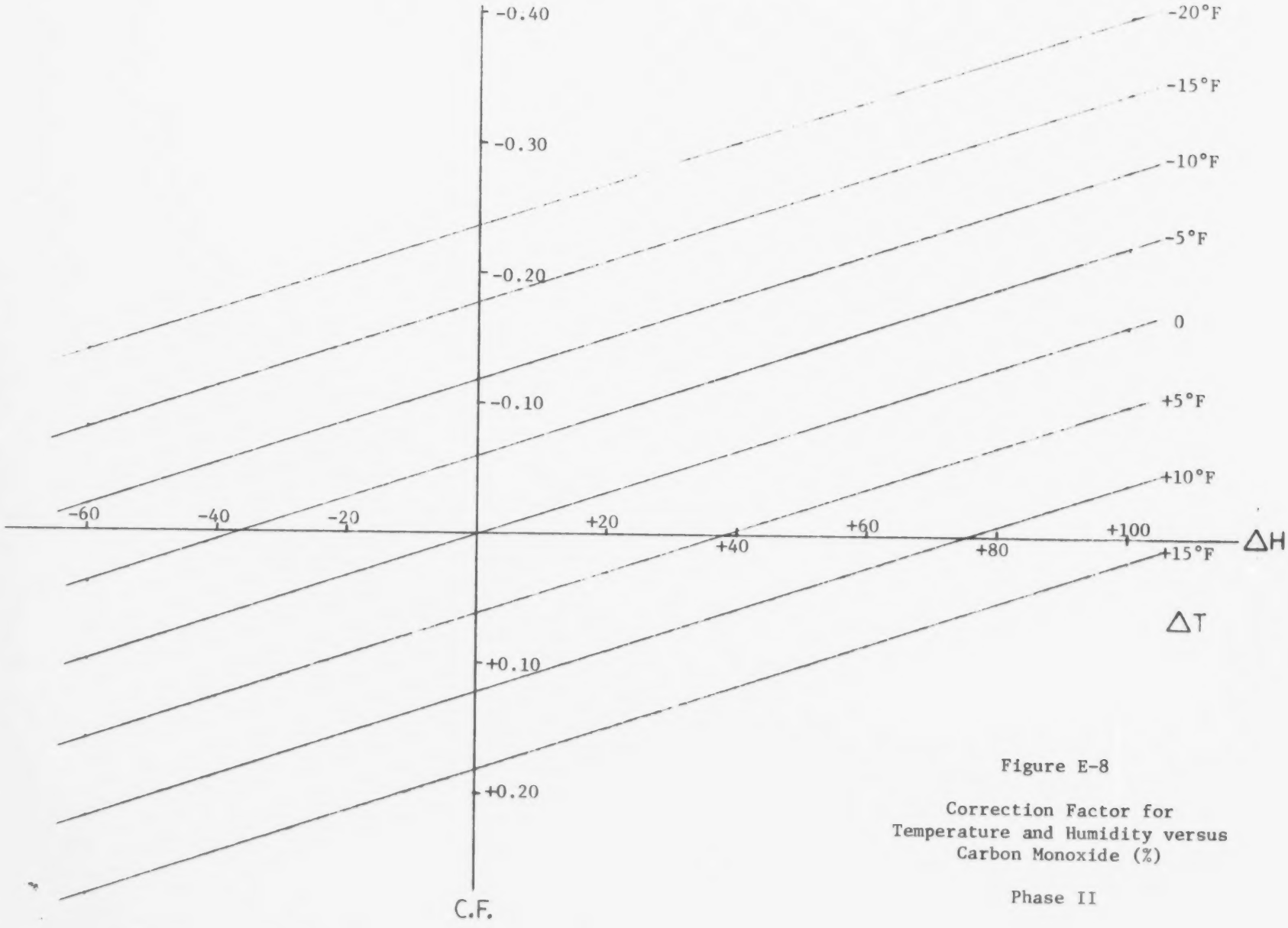

Figure E-8

Correction Factor for
Temperature and Humidity versus
Carbon Monoxide (%)

Phase II

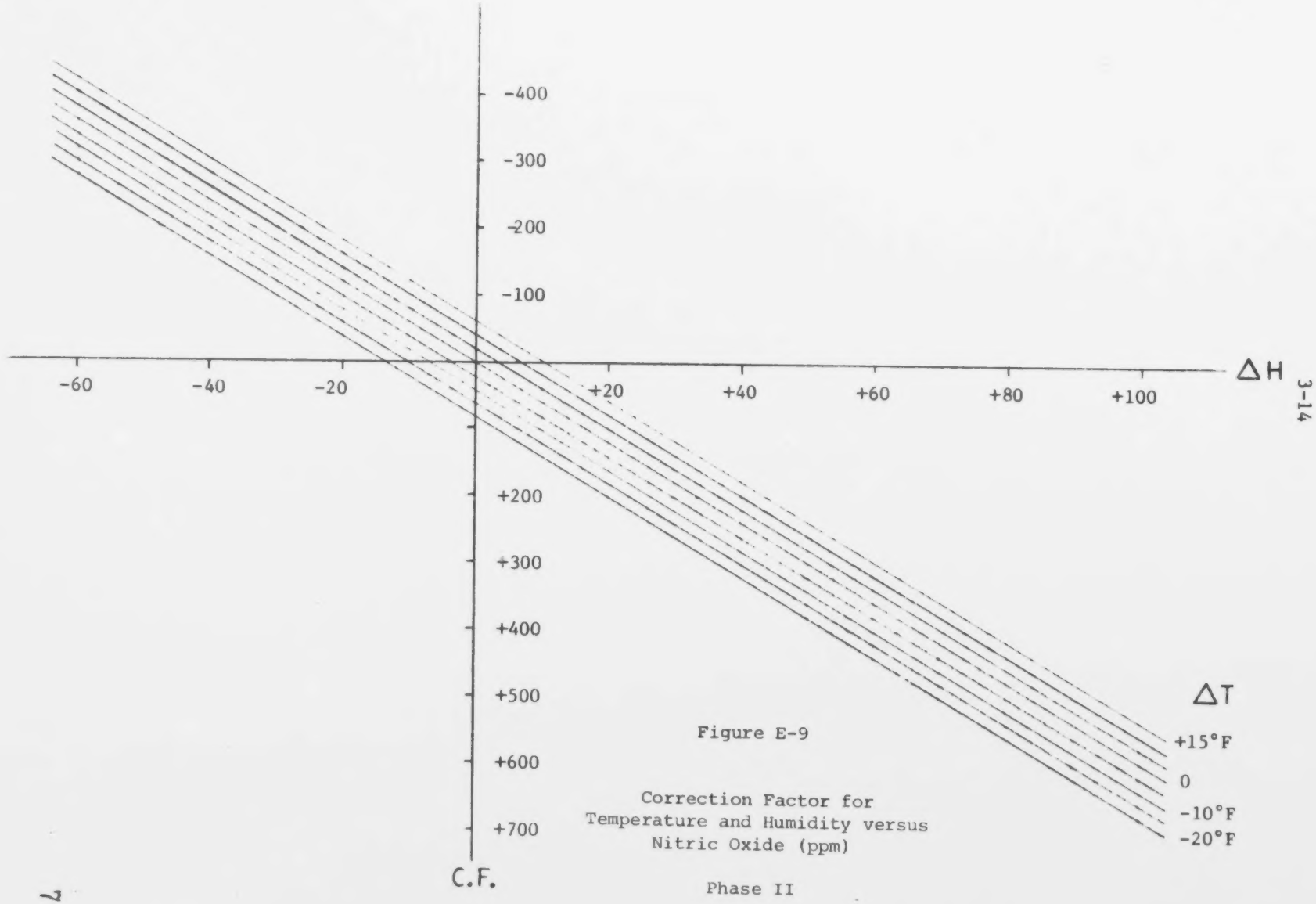

Figure E-9

Correction Factor for
Temperature and Humidity versus
Nitric Oxide (ppm)

Phase II

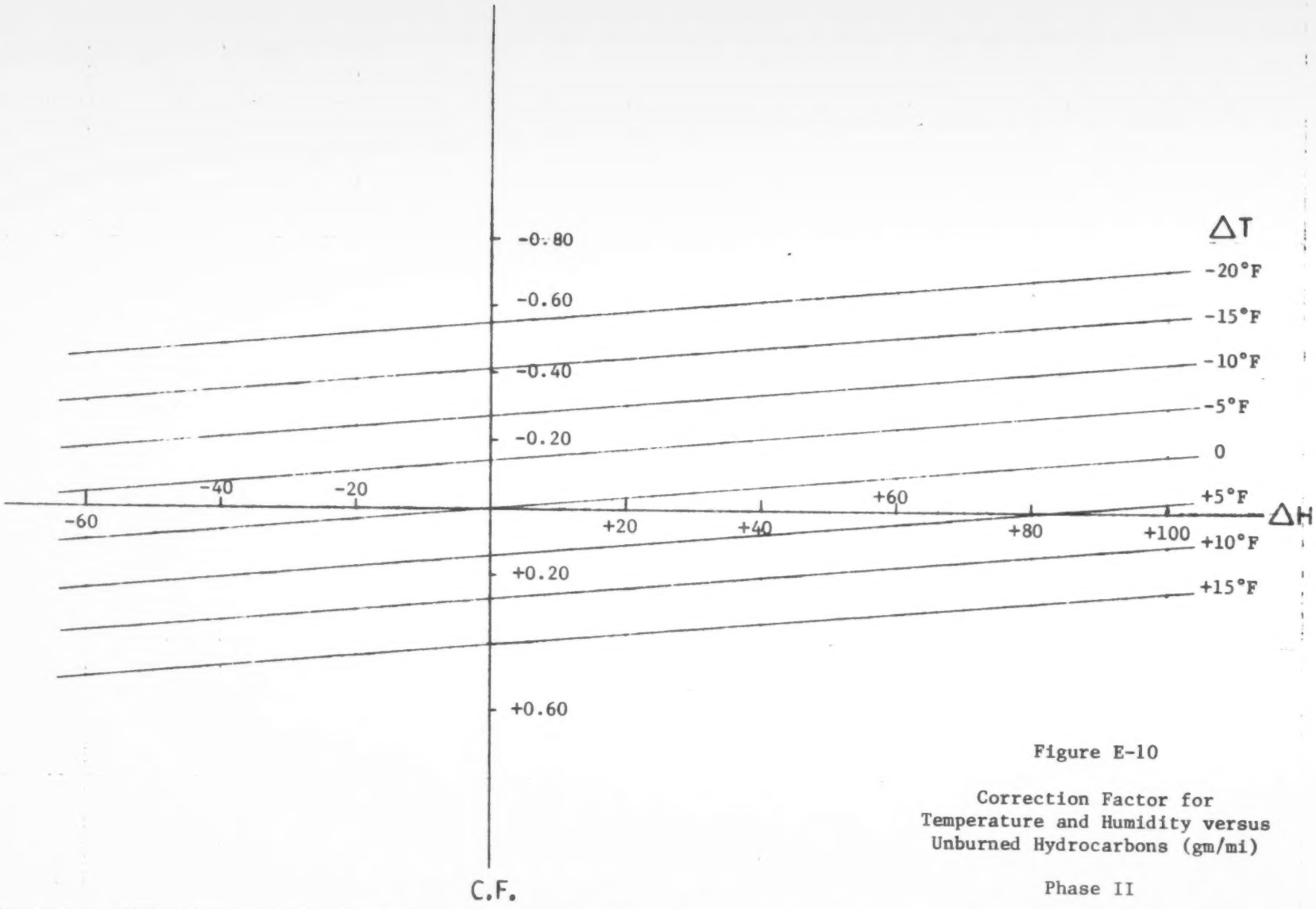

Figure E-10

Correction Factor for
Temperature and Humidity versus
Unburned Hydrocarbons (gm/mi)

Phase II

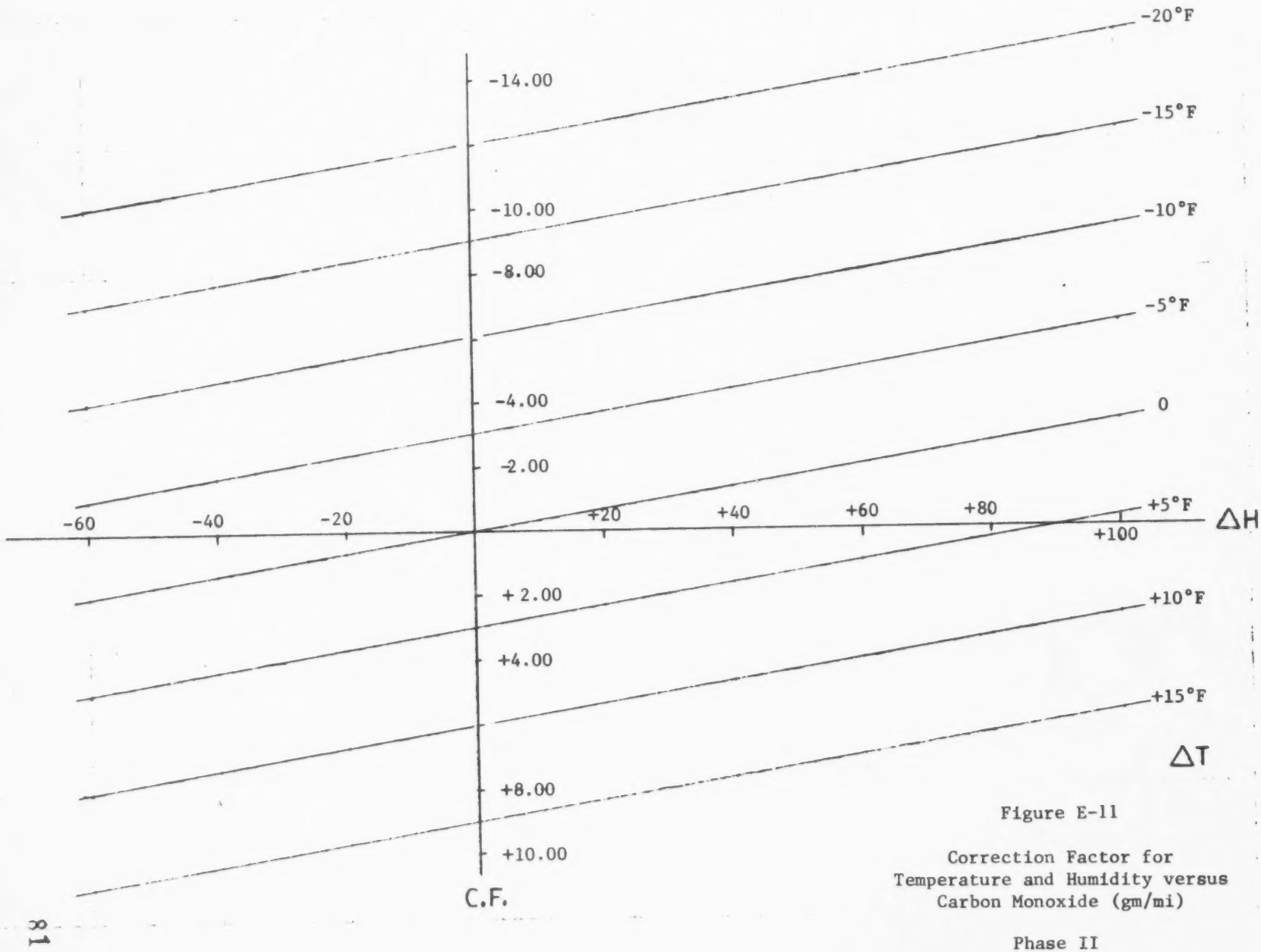

Figure E-11

Correction Factor for
Temperature and Humidity versus
Carbon Monoxide (gm/mi)

Phase II

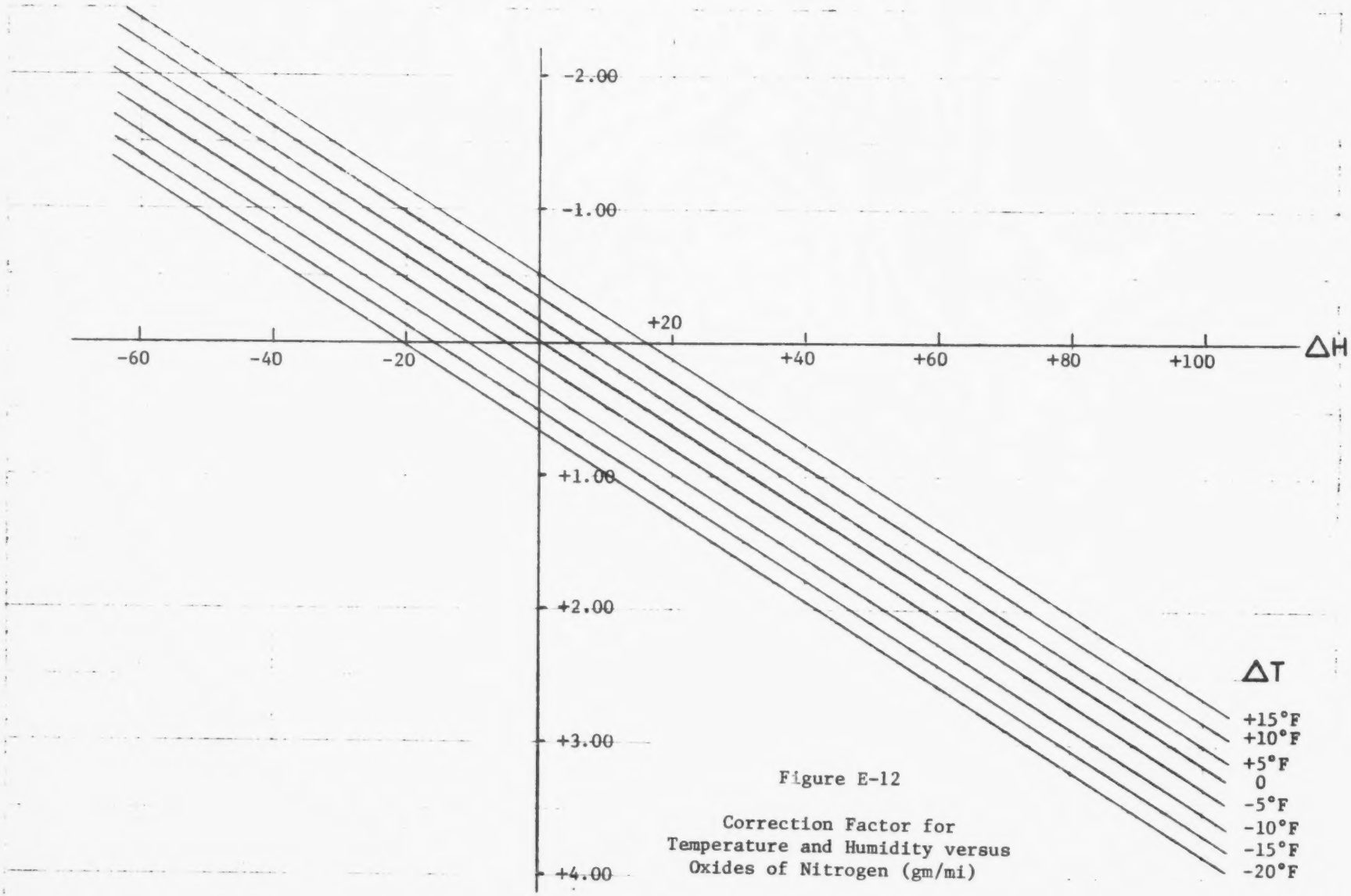

Figure E-12

Correction Factor for
Temperature and Humidity versus
Oxides of Nitrogen (gm/mi)

Phase II